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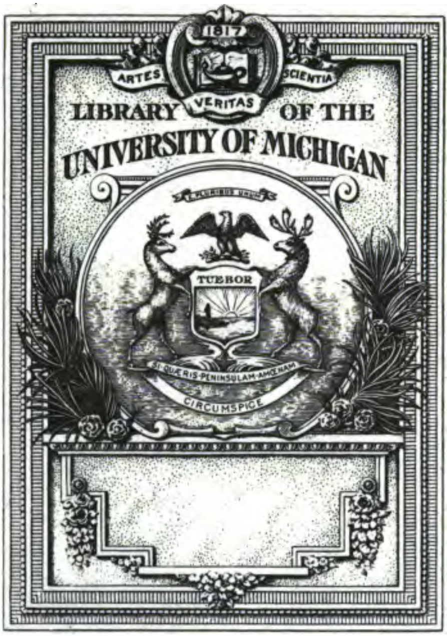

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LONDON, 1883

FISH CULTURE

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BY

FRANCIS DAY, F.L.S.
COMMISSIONER FOR INDIA TO INTERNATIONAL FISHERIES EXHIBITION

ILLUSTRATED

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FISH CULTURE.

FISH culture comprises several objects, the chief of which are an augmentation in the number, and an improvement in the breed of the fishes of a district, country, or even of the ocean, by means of direct cultivation, not only of the finny tribes but also of the food upon which they subsist. It likewise embraces whatever facilitates their ascent and descent of rivers, rendered necessary for spawning purposes to continue the race, or for nutriment to maintain the life of the individual. Many of these subjects appear to have received more consideration in ancient than in modern times, and up to a recent period, in distant countries, as China, than in more civilized Europe.

The Chinese are commonly credited with having been the people who first turned their attention to fish culture, collecting and disseminating the spawn, and artificially rearing fry which they employed for the purpose of stocking every available piece of water. The Egyptians likewise in times past must have taken considerable pains in this occupation, but it has been surmised that their earlier vivaria were of two kinds, sacred and profane, the occupants being destined for either the altar or the table. The boundaries of ancient Egypt are well known, and the conformation of the barren deserts on its east and west show but little alteration: but her population must have largely diminished, for we are assured by Diodorus that 1700 Egyptians were born on the same day as Sesostris, which would represent a population that could not be less than 34,000,000. The agricultural resources of the country would have been far too small to supply sufficient food for such multitudes, and a fish diet must have been largely partaken of. At that period fish culture was extensively practised, and the ruling powers and the ruled vied with each other in augmenting the fish supply in all the numerous tanks, lakes, canals, and rivers of the country. Lacépède computed that Lake Mœris alone might have produced 18,000,000,000 fish of two feet long each.

In the Roman republic fish culture was carried on for the purpose of augmenting the general food supply, and Belonius observes that the waters of the Propontis were more profitable for the fishes they produced, than a similar extent of the best land could have been by its pasturages and its harvest. Lucullus, we are told, dug large trenches or canals from his fish ponds to the sea in the vicinity of his house at Tusculum, in the Gulf of Naples. Fresh-water streams ran down the canals to the sea, and up them sea-fish which spawn in fresh water or anadromous forms, ascended to deposit their ova. When these fish had entered, the gates at the exit of the canals were closed, and while their eggs were developing into young and growing to an eatable size, the parents which had spawned were being employed as food. Varro observed that there existed two forms of stews, the one supplied by fresh, the other by salt water—In the first, advantage being taken of springs and the conformation of the ground, constituted the poor man's pond, whereas none but the rich could enjoy the proceeds of a sea preserve: this latter being pleasing to the eye but expensive to the owner and better adapted to empty his purse than satisfy his appetite. But in time some individuals who had studied fish culture to advantage made large fortunes by salt water vivaria. Roman authors have left us detailed accounts of how their various stews were formed, subdivided and supplied with water; how exotic fishes were sometimes brought from long distances; how their sea ponds were usually stocked from the neighbouring ocean; and lastly, how they obtained fish spawn in the sea which they successfully reared in rivers and lakes. While the high admiral Optalus under Claudius brought from the Carpathian Gulf vast supplies of the hitherto unknown fish, Scarus, and deposited it along the coast from Naples to Ostia, where he continued to cruise about and inspected the fishermen's nets for five years, during which period he suffered none of the species to be captured.

The discovery of how to artificially fecundate fish ova has been claimed for many different persons, in various ages, and in widely separated countries. In the fifteenth century a monk named Dom Pinchon appears to have practised it, breeding and rearing fishes in wooden boxes through which a stream of water flowed. The bottom of these boxes he lined with sand or gravel, while their ends were protected by wicker basket-work. Stephen Ludwig Jacobi, a wealthy landed proprietor, residing at Hohenhausen, a small town in Westphalia, as early as 1758 appears likewise to have made many experiments respecting the artificial breeding of salmon and trout, adopting much the same plan as Dom Pinchon, except that he secured both the upper surface and ends of his troughs with fine gratings and deposited them in the stream at a suitable depth leaving the eggs to be naturally hatched. He gave an account of his discovery in a letter to Buffon, which was deemed so important that the British Government granted him a pension.

Lacépède, writing at the commencement of this century, deplored the loss of fish-ponds in France, remarking that formerly they produced large returns, but had then ceased to yield anything, so that much evil and no good has attended their abolition. In Germany the landowners make more by their carp and pike than many agriculturists obtain in Great Britain from their sheep and cattle kept in a similar space. In this country stews were attached to most large houses in the country, and every monastic establishment, but with the emancipation from fasts and greater facilities of transit from place to place the necessity for these vivaria diminished or almost disappeared. It is only now that meat is becoming so expensive, and likewise fish, due to pollution of waters and too much license having been permitted to fishermen and poachers, that the necessity appears to have arisen for some remedy for the present dearth of the finny tribes as shown by its excessive cost.

To the French Government is due the credit of first turning fish culture in Europe into practical channels. In 1842 they commenced their experiments, and in 1848 the establishment at Huningue came into existence near the Rhine and the Rhone canal, while it possessed springs in the vicinity which could be utilised for the incubation of fish eggs. Here but comparatively few of the ova were hatched, for when the eyes of the embryo became visible, showing that they might travel with comparative safety, they were distributed to wherever it was considered they could be turned to the best account. When this establishment first commenced work, the rivers and lakes of France were exceedingly deficient in fish, but by a distribution of about 20,000,000 ova annually they became restocked.

In Great Britain, as already remarked, the Government appear to have been one of the first in Europe to appreciate the importance of Jacobi's re-discovery of how to artificially impregnate fish ova. In 1837 Mr. John Shaw succeeded in fecundating and hatching salmon eggs, also in rearing the young; while Gottlieb Boccius asserted that he had successfully reared young trout at Chatsworth and Uxbridge as early as 1841. The Galway salmon fisheries were restocked by Messrs. Ashworth by means of artificial propagation in 1854. In Scotland the establishment of Stormontfield was commenced in 1853 on the Tay, the rental of that river in 1828 being £14,574, but which gradually diminished until 1852, when it had decreased to £7,953. In 1858, the rental rose to £11,487, and in 1862 it had reached the value it had in 1828. This rise not being due to increased value of salmon in the market, but to augmented numbers of fish in the river.

As animal food becomes dearer, and the price of fish augments, it is remarkable how British fisheries have been treated, and the slight amount of statistical evidence which has been collected and made public, while no Government official is now engaged on the artificial propagation of fish, or in experiments upon how to augment the supply of this necessary article of food. In fact, the British Government, respecting freshwater fisheries, is now behind almost every country, in that it gives no assistance to the fish culturists, and keeps up no establishments of its own in order to maintain the necessary number of fish in our waters.

In Norway pisciculture commenced about 1850.

In Germany, artificial fish breeding has become extensively disseminated in all parts of the country, while their natural propagation is carefully tended. Likewise the cultivation of fish ponds is assuming an importance they have not had since the abolition of monastic establishments.

In Italy, lagoons appear to be somewhat extensively employed by the fish culturists, who capture young fry in the sea and rear them in these large vivaria.

In Greece the state maintains twenty-four establishments for fish culture, the principal being in lagoons, and the captives being disposed of while in a fresh condition.

In the United States of America a Fish Commission was first appointed in 1871, to investigate the alleged diminution of food fishes along the sea coast and in the lakes, and if this proved to be the case, to suggest the proper method for restoring the supply. The next year an additional feature was ingrafted, namely, that of the propagation and actual multiplication of the food fishes. Subsequently a large proportion of the various States, satisfied with the excellent work being carried on, organised State Commissions for the purpose of looking after the interests of their waters, and of co-operating with the United States Commission towards the accomplishment of a common end. In 1879 the Congress authorized the construction of a special steam vessel of 484 tons, to serve as a floating station for the hatching of shad and other useful food fishes.

Professor Spencer Baird, when reviewing the impoverished condition of their fisheries, and the measures which he deemed advisable, observed: "What are now the remedies to be applied, to recover from this lamentable condition of the American fisheries? These are twofold: one consists in the enactment and enforcement of legislation protecting what we have, and allowing natural agencies to play their part in the recovery; the other consists in the application of the art of the artificial propagation of the fish. Either alone, in some circumstances, will answer a very good purpose; the two combined constitute an alliance which places at our command the means of recovering our lost ground to a degree which, but for the experience of the last ten years, would hardly be credible."

The active field work of the Commission, observed the Commissioner in 1875, now embraces almost the entire year. The hatching of shad, *Alosa sapidissima*, continuing from March until August; of Californian salmon, *Salmo quinnat*, from June until November; of Penobscot salmon from June until March or April; of landlocked salmon, *Salmo salar* variety, from September until March; and of white fish, *Coregonus albus,* from October until March. Since then cod and other tribes have been added to the species of fish artificially propagated.[1]

The far-famed Columbia river, where the abundance of its salmon has been a theme for astonishment among those who have witnessed it, began to show signs of decreased supply. The canners took alarm, and petitioned for legislation, to be accompanied, if possible, by artificial propagation, and in 1876 a permanent station for this purpose was opened on the McCloud river.

In the Sacramento river, observed Professor Spencer Baird, the catch has increased in five years from five millions to fifteen millions of pounds, and has brought up the supply to more than its pristine condition of abundance, by planting about two millions of young fish every year. In the Rogue River, Oregon, where salmon had for nearly twenty years been taken in large numbers and salted, a visible diminution became apparent in the season 1877–1878, and it was decided, in consequence, to commence their artificial propagation.

In the Dominion of Canada, Mr. S. Wilmot originated fish culture, and under his management the work is largely carried on. He states that some hundred millions of young salmon have been artificially hatched and distributed in the waters of the Dominion during the last few years, and now (1882) Government hatcheries are constantly being erected. It has been clearly demonstrated in this Dominion, by Mr. Wilmot and others, that by artificial propagation and a fair amount of protection all natural salmon rivers may be kept thoroughly stocked with this fish, and rivers that have been depleted through any cause, brought back to their former excellence. In Restigouche river, where no obstructions existed, but spearing and netting were relentlessly pursued, the number of salmon had so decreased, that in 1868 anglers only took 20 and the commercial yield was merely 37,000. A salmon hatchery was then inaugurated, and a little protection afforded to the fish, and in 1878 one angler alone, out of hundreds that were fishing in the river, killed in 16 days with his single rod 80 salmon, 75 of which averaged over 26 lbs. each; while in that one division (not counting local and home consumption) net fishermen took 500,000 lbs., a result largely brought about by artificial cultivation. Also in the Saguenay River the scarcity of salmon had become so great that there were no lessees; a hatchery was built, and the state of things wonderfully changed, so much so that in 1878 from the great numbers of salmon taken in the tidal waters they became a drug in the market, and were selling as low as 3 cents a pound, and angling in the tributaries was most excellent.

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[1] In Mr. Brown Goode's paper on the Fishery Industries of the United States he enumerates 27 species or varieties of fish artificially hatched in that country.

The Canadian fisheries report for 1882 shows a very large increase of salmon in the rivers, where artificially bred fry were planted; and the returns from the Restigouche, and Gaspe, up to the first half of the season of 1883, give an almost unprecedented catch of fish by anglers. On the Restigouche, at the Metapedia pools, 300 salmon were taken in one week, averaging 22½ lbs. Three miles higher, 56 fish, average weight 23 lbs:—Farther up a party of four rods killed 190 salmon, 23¼ lbs. average:—At Indian House, Wilmot's pool, four rods in two weeks caught 180 fish, all very large, one a forty-pounder:—Another party in same pool killed 55 salmon:—In six pools still further up-river, 386 salmon were taken by 14 rods in a fortnight's time: in one of the above pools, 36 salmon were killed by three rods in one day:—On this river a large salmon hatchery has been in operation for several years:—At Gaspe another hatchery is in operation, where in 1882 the report shows an increase over former years; but in 1883 the catch has been threefold over 1882.

In Japan the Government have taken steps towards carrying on a complete system of fish culture, for the purpose of restocking rivers which appeared to have become depleted. The first stations established were those at Yuki, Kanagawa Ken, and at Shirako, Saitamo Ken in 1877. At either of those stations, 30,000 fish can be raised. In 1879 the number of establishments was augumented to five; and at Shiga Ken, which has an abundant supply of water at 54° Fah. in the summer, there is a capacity of raising any number of fish: lake trout were introduced, and there were 40,000 fish 18 months old in good condition, as well as 250,000 young fry. Unable to obtain a sufficient supply of meat, the fish are fed on a mixture of the chrysalides of silk worms and wheat-flour. Equal portions are ground up together in a coffee mill, the mixture is boiled for fifteen minutes and then allowed to cool, subsequently it is pressed through a fine wire sieve. Hatching fish is said to have been first adopted by Aodo two hundred years ago, and the Daimio of that time made rules for the protection of the fish and fry which are in force to this day.

OUR FRESHWATER FISHERIES.

Our inland waters may be roughly divided into those found in rivers, canals, lakes, broads and ponds: while in rivers we have such as are rapid and clear, or else sluggish and more or less muddy. In these various localities we find different varieties of fish, which may be classed into game-species, as salmon, trout, and their allies; and secondly, coarse fish, as perch, carp, pike, &c. In the foregoing enumeration shad are omitted as well as flounders and lampreys, which ascend into fresh waters from the sea.

Although in some localities rivers and their piscine inhabitants still continue in an almost primitive condition, in the vast majority of cases in Great Britain and Ireland artificial causes, often due to augmented population, have led to changes which have entirely altered what was the former aspect of affairs. For although in sparsely inhabited places where the local demand is small, and the means of transport to cities difficult, man in his efforts rarely occasions any undue decrease in the finny tribes inhabiting the fresh waters, yet as population augments a very perceptible change ensues. Land becomes more cultivated and better drained, towns spring up on the river banks which may possibly in olden time have been the natural highway of the country: first surface drainage, next sewerage, become emptied into its course, and, finally, manufactories rise, the owners of which find it cheaper to use the river as the receptacle for their poisons than to dispose of it in pits and other innocuous ways. Thus fish become destroyed, or their health affected, as well perhaps as whoever or whatever partakes of these polluted waters. Mines in a similar way may be drained into streams, weirs may be constructed to span its course, immoderate netting and poaching practices may be legalised, and one or all of the foregoing causes may occasion a diminution in the stock of fish. The water, instead of providing an augmented supply of food to an increasing population, becomes, as years roll on, more and more depleted of fish, and either legislative aid must be invoked to remedy what the legislature itself has to a considerable extent occasioned, by first tolerating and subsequently legalising flagrant abuses: or else the rivers must by artificial means be annually supplied with fish from elsewhere, to compensate for the unnatural depletion which is being carried on by man.

The question may be asked whether our fresh-water fisheries are in an impoverished state?—if any apparent diminution is not due to increased facilities of transport causing fish to be now distributed over a wider expanse of country than was formerly possible? Due to the absence of statistics, any investigation into these questions is difficult but not impossible, and I purpose adverting to the condition of the salmon fisheries, as being the most valuable in our fresh-waters, and consequently those best known.

The first fact that strikes the investigator is that salmon have been exterminated from the Stour, the Itchen, the Medway, the Avon, and the Thames, in England. In Scotland the Fifeshire Leven no longer contains salmon; in the Tay district the Almond, Ericht and Dighty are ruined, due to pollutions, while many other rivers are greatly injured. In Ireland, from Wicklow Head to Rossan Point, nearly every river in the county Down has, owing to pollutions, been destroyed as a salmon producer. The foregoing instances are adduced to prove entire destruction in some localities.

It has been asserted that in ancient times the supply of salmon was so abundant that, in indentures of apprenticeship, a proviso was usually inserted that the apprentice should not be compelled to eat salmon more than three days in the week. In Coursell's 'History of Gloucester' it is stated that "it was a standing condition of apprenticeship that the apprentice should not be obliged to eat salmon more than thrice a week." This proviso is alluded to as existing at Worcester, Newcastle, and elsewhere, while the Cromwellian trooper, Captain Franks, writing of Stirling, remarked that the burgomasters, as in many other parts of Scotland, are compelled to re-enforce an ancient statute that commands all masters and others not to force or compel any servant or an apprentice to feed upon salmon more than thrice a week. At Inverness, a century later, Burt tells us salmon sold at one penny a pound.

We are however reminded that it is difficult to compare the price charged a century since to what obtains in the present time, because so many disturbing influences have occurred. Pennant, in 1776, tells us that to pay the expenses of the salmon fisheries in the river Tweed, it would have been necessary to capture 208,000 salmon annually, an amount which must have far exceeded the supply in the present day. If however for the sake of argument it were admitted that there is no diminution in the number of our fresh-water fishes, he would be a bold individual who asserted that our rivers and other fresh waters are as fully stocked as the sustenance in those waters could maintain.

Some of our fishes have seriously decreased in number, and our fresh-water fisheries require more attention than they now receive in order to render them the food producers they ought to be. But, prior to considering artificial propagation, it will be necessary to advert to what kinds of fishes we possess which are worth increasing, and what are the characters of their eggs.

DIVISIONS OF FISHES.

Our fresh-water fishes are divisible into the river or fluviatile and lacustrine or lake species, while our marine fishes may be considered as shore or littoral, and pelagic or sea forms, these last being again subdivided into such as are generally found near the surface, at greater or mid-depths, and abyssal residents. Fishes which frequent fresh water may be permanent residents therein, as carp; anadromous, or merely visitants from the ocean for the purpose of depositing their spawn, generally leaving their young to be reared there, as salmon and shad; catadromous, or such as reside in fresh water, visiting the littoral zone or sea to deposit their spawn, as eels, the young of which ascend our rivers in order to be reared.

BREEDING OF FISHES.

Fishes are diœcious animals, the sexes being present in different individuals, although in some exceptional instances hermaphrodites have been recorded. A few are monogamous; but the majority are polygamous. Among the bony fishes breeding takes place on one of the following plans, (1) the eggs may be hatched within the female organs as seen in the oviparous blenny; or (2), as in the majority of these fishes, the eggs having been extruded by the female, are subsequently fertilized by the male, the milt of the latter being brought into contact in the water with the hard roe of the female. Simple, however, as this process may appear, there are many interesting questions respecting breeding which demand the attention of the fish culturist, such as what is the size of the eggs, whether the fresh-water forms deposit theirs in stagnant, semi-stagnant places, or running streams; or do those of the sea species float, as of the cod, sink, as of the herring, attach themselves by tendrils, as the gar pike, or by adhesive mucus as in lump suckers?

The forms which produce the greatest number of eggs are often those which live in large communities, spawning once annually, as the cod; from a 21 lb. example of which 12 lb. of roe were obtained, while Buckland found that 7½ lb. of roe contained 6,867,000 ova; which, if the proportions were the same in each, would give the enormous number of about 11 millions of eggs in a 21 lb. cod-fish. A perch gives from 20,000 to 28,000: mackerel at 1lb. 86,120, at 1⅛ lb. 546,681 eggs. From a brill of 4 lb. 239,775, from a plaice of nearly 5 lb. 144,600, from a flounder of about

1½ lb. 1,357,400, from a sole of 1 lb. 134,000. Among the Salmonidæ the eggs are generally comparatively large, the number which each salmon produces being estimated at about 900 for every lb. of its weight; but they may exceed this, as one of 20 lb. contained 27,850. This variation in size is perhaps, partially at least, due to the age and size of the parent, thus in the report of the United States Fish Commission on the McCloud river, California, it was observed in 1878 that the parent salmon were unusually small, their average weight being under 8 lb. This small size was stated to be undoubtedly caused in whole or in part, by the fishing at the canneries on the Sacramento, where the 8-inch meshes of the innumerable drift nets stopped all the large salmon, and let all the small ones through. The eggs when taken proved to be at least a third smaller than those of most previous years, and the average number to the fish was about 3,500 against 4,200 in the previous year. Possibly fry reared from eggs of salmon fertilised by the milt of the parr would be rather a small race. Similarly at Sir James Gibson Maitland's fish-hatching establishment at Howietoun, the Lochleven variety of the common trout at 4 or 5 years old produced eggs 32 of which filled one length of a glass grill in the hatching boxes; but such as were obtained from 6 year old fish, 27 or 28 eggs occupied the same amount of space. Livingston Stone observes[1] that American trout living in spring water develop smaller ova than such as reside in brooks. Although fish producing smaller eggs may have proportionately more in comparison with their weight, young reared from such ova are neither so large nor grow so quickly as such as are derived from eggs produced by older fish, and it has appeared to me that such may be one cause of how some races of fish may deteriorate.

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[1] He likewise considers that "large eggs are the result of keeping the breeders in water that warms up in the spring and summer. It is true, if it becomes too warm, say above 70°, it is injurious; but water that stands at 65° in the summer will make larger eggs than water at 55°, and very cold spring water will always develop small eggs" (p. 183).

From a 21½ lb. carp, 1,310,750 eggs were obtained ; from a 16½ lb. example, 2,059,750 : from a roach ¾ lb., 480,000 ; of 10½ ounce, 81,536 : a tench of 2½ lb. contained 383,252. Herring, from 20,000 to 30,000 eggs. The foregoing figures show that a great margin must be allowed to be present in the number of the eggs produced in each variety of fish, owing to the size and age of the parents, the character of the water in which they reside, and other physical conditions. The great numbers produced by some forms are evidently intended for the purpose of counterbalancing the enormous waste which must necessarily occur under some natural conditions, but they may be insufficient to supply the deficiency caused by man.

The places where fish eggs are deposited are exceedingly various. Thus the ovum of the cod, which possesses no oil-globule, floats in sea-water until the young emerge, consequently the micropyle is at the under surface, the milter is below the spawner and the milt ascends : in the herring the ova sink to the bottom, where by means of a glutinous secretion they become attached to seaweeds, rocks, and other objects. One form of sea-sucker (*Lepadogaster*) affixes its eggs to the inside of an old shell, as a butterfly does to a leaf : the gar-fish has filaments springing from the outer covering of its ova which enables them to adhere together in a mass, or attach themselves to contiguous objects, possibly with a view to prevent their sinking into the mud. Anadromous forms appear to deposit their eggs in pieces of running water, but in different ways ; thus, the smelt attaches its ova by a filament to planks, stones or posts near high-water level; the grayling deposits its ova in the bed of rivers; the salmon and trout cover their eggs with sand and gravel; while other fishes, in fresh water, spawn in muddy ponds or slowly flowing rivers, where the eggs of the salmonidæ would never, as a rule, arrive at maturity. The ova of the perch are about the size of poppy-seeds, and instead of being deposited separated one from another, as in the salmonidæ, have them adherent together by a glutinous substance with stringy bands or mesh-work, much resembling frog spawn. The perch selects a spot where rushes, reeds, or grass grows in the water, or else seeks a piece of wood, or some hard substance, against which she rubs herself or presses, until one end of the band of ova has become attached, and then, gently swimming away, the eggs are voided. The stickleback, whether marine or fresh water, forms nests for the reception of its eggs. The river bull-head deposits its spawn in a hole it forms in the gravel, and quits it with reluctance. In tufted-gilled fishes, as the pipe, or horse-fish, the male performs the function of hatching the eggs, which for that purpose are deposited, and remain up to the period of the evolution of the young, attached between the ventral fins, as in *Solenostomus*, a form of pipe-fish; in tail pouches in horse-fishes; or merely in rows, as in *Nerophis*.

A problem requiring solution is why the floating eggs of marine fishes are not cast ashore to perish. Generally they are not deposited too close in shore, while waves move floating substances very slowly. The wind does them no injury, as they protrude but little above the surface, and not at all during storms. They float about, scattered or singly, and many animals eat them; but their transparency is some protection.

Mr. Ryder, in the United States, has made some exceedingly interesting observations upon the mechanical conditions affecting the development of fish ova, some of which are as follows. Among salmon, charr, coregoni, and smelts, he found an abundance of oil-drops imbedded in the vitellus, but most abundant under the germinal disk ; as the specific gravity of this oil is less than that of water, their aggregation underneath the disk tends to keep the latter directed constantly upwards. If the egg is turned, the buoyancy of the oil-drops at once turns the vitellus within the yolk membrane, and brings it to rights with the germinal disk looking upwards. Another type of egg is seen in cusk, crab-eater, Spanish mackerel, and moon-fish. In all the egg is kept buoyant, due to the presence of a single large oil-sphere, situated at a point almost exactly opposite the germinal disk, which is constantly inverted, or carried on the lower face of the vitellus, thus acting exactly the reverse, as observed among the salmonidæ. No oil-drop exists in the egg of the cod,[1] but the specific gravity of the vitellus is so slight that it behaves exactly like the foregoing—the germinal disk being constantly directed downwards. In the egg of the white perch (*Morone Americana*), which is adhesive and fixed, a very large oil-sphere is imbedded in the vitellus, which controls the position of the latter, and keeps the disk inverted, and on the lower side of the vitelline globe, while the free uncovered portion of the latter is always directed upwards, at least during the early stages. The shad has an unusually large water space around the vitellus, between the latter and the egg-membrane ; but the egg is not adhesive, and its specific gravity is greater than that of the water in which it is immersed. There exists a constant disposition of the germinal disk to arrange itself at the side of the vitellus when viewed from above, though there is no oil in the vitellus to influence its position. In the plectognath (*Aleuteres*), a cluster of oil-drops is imbedded at one side in its yelk or dentoplasm, while its germinal matter or protoplasm is relatively large in amount. In the Cyprinodont (*Fundulus*) and the pipe-fish (*Syngnathus*), the oil-drops appear uniformly distributed and imbedded in the superficial portions of the yelk next to its external surface. This brings the deposits of oily matter into close proximity to the vessels traversing the vitellus. The function of these oils, aside from their buoyant tendencies, as in these last cases, is not clear; and, beyond the fact that they are evidently absorbed together with the remainder of the yelk, we know little of their nutritive properties. Perhaps in the process of physiological decomposition these oils of fish embryos develop heat.

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[1] Because the eggs of the cod-fish float it must not be taken for granted that those of all the family do so. The United States expedition have found the eggs of the hake and the young at 100 to 200 fathoms' depth.

But it does not appear as if fishes were invariably able to extrude their eggs without extraneous assistance; thus, Carbonnier and others have recorded how, in the gold carp, the male, or sometimes two or more of that sex, have acted as accoucheurs to the female. One heavy in spawn has been observed being rolled like a cask upon the ground for a distance of several metres, and this process has been continued without relaxation for two days, until the exhausted female, which had been unable to recover its equilibrium for a moment, had at last evacuated her ova. It has been observed of the lampern, or river lamprey, that while breeding, one twists its tail around another, these two fishes being invariably of opposite sexes, and that the ova and milt are discharged at this time. It is likewise remarkable that, should conger eels be kept some time in an aquarium, the female appears to die at spawning time, as if due to the absence of the male from assisting in the extrusion of the eggs. It is thus seen that it does not follow that fishes must extrude their ova when such have arrived at a certain period of development, a subject of some importance, especially in the salmon family. Thus, at Howietoun, it has been found that retardation is possible, if the ripe fish, whether male or female, is placed in a box with smooth sides, and through which a current of water passes.

Salmon enter suitable rivers for breeding purposes in varying numbers throughout the year, unless impurities have annihilated the breed, as in the Thames. At certain times, as during the cold season, they deposit their fertilised eggs in nests or redds, subsequently descending to the sea in a miserable condition, many of the males succumbing from exhaustion, while at these periods their flesh is positively unwholesome.

Experiments have been made as to whether, should salmon eggs be deposited within tidal influences, they would hatch; or should the young come forth, whether they could live, as (due to droughts, pollutions or artificial obstructions) ascent might be rendered all but impracticable. Investigations have shown that if salmon ova are deposited within tidal influences, salt water is fatal to the fertilising property of the milt or to the life of the impregnated egg. In Canada, Mr. Wilmot finds that there is no necessity for salmon ascending rivers to breed, or obtain access to fresh water, as he finds that they can be caught at sea about May, and impounded in ponds into which the tide ebbs and flows, until they become ripe in October or November, when they are artificially spawned directly from these salt-water vivaria, and the eggs deposited in fresh-water troughs in the hatcheries. Mr. Wilmot considers the young, thus reared, stronger than from ova obtained from rivers. Mr. Livingston Stone tried catching salmon early in the season in the McCloud river, and, by confining them, to have a large number ready at the spawning season. But they mostly died after a week or two. Some were placed in large plank boxes anchored in the river, and having great apertures to insure a good circulation of water; others in large pens in the bed of the streams, or in ponds on shore, supplied with a constant stream of river water. The imprisoned fish spent their whole time in efforts to escape, but day after day they died; the more caught, the more were lost. Since then, better results have been obtained.

The eggs of salmon are small, round, elastic bodies of a clear white, pink, or coral colour, possessing a tough outer coat, as may be ascertained by throwing one on the ground, from whence it will rebound without breaking. This strength and elasticity must be a very important property, considering where these eggs are to be deposited, and what an amount of pressure they may have normally to undergo. For the young are hatched in localities not where a strong current would wash them away, but in small and often almost mountainous streams, where the water is pure, shallow, and passes over a gravelly bed in which the redd can be constructed, while deep pools in the vicinity allow the breeding fishes to retire into them for rest.

The milt, soft roe, or seminal fluid of the male, is of a thick milky appearance, which under the microscope is found to consist of innumerable microscopic organisms termed spermatozoa or zoösperms, resembling a small head with an elongated tail-like posterior portion. During the period of their existence they are extremely active, in constant motion and restless activity. If placed in water, the term of their existence is rapidly cut short, although a good deal depends upon the temperature at which this is done; but the duration of their active lives in this situation has been computed by different investigators at to thirty minutes, but two to two-and-a-half would appear to be nearer the truth. These spermatozoa are naturally living in an alkaline fluid, composed partly of phosphates and partly of other constituents, and here they will live for days, even after leaving the fish; if, however, water is added, these spermatozoa are rapidly killed. M. Vrasski kept them alive six days in a tightly corked bottle, whereas they died in two minutes in water after having been removed from the fish. These experiments have been turned to practical account in the artificial spawning of fish.

The egg or ova has on its surface a microscopic orifice, termed the micropyle, which is usually considered to be for the purpose of allowing the entrance of the spermatozoa, without which it would be unfertilized and barren. These eggs as extruded are soft, and rapidly absorb, through the micropyle, water or spermatozoa or other substances, and thus fill up the interspace between its strong elastic outer and its delicate inner covering. After this absorption is over, it is impossible for the ova to be fertilised. It has been computed that, this absorbing power in trout eggs lasts thirty minutes; but this is probably a maximum. If, therefore, trout eggs are mixed with milt in water, it is evident that, unless fertilisation rapidly takes place, the spermatozoa will have perished. On the other hand, if no water is employed, but sufficient milt stirred about and among the eggs, theoretically the probability would seem to be in favour of the absorption of the vivifying principle, and facts fully bear out in practice the accuracy of this supposition. I have already alluded to the great variation in the size of the eggs due to the age of the fish; but the general computation in Scotland is as follows: Salmon, 25,000 to the gallon; Lochleven trout, 30,000; brook trout, 40,000; American brook trout or charr, 80,000.

The spot where the salmon redd is to be formed in the river or stream having been selected, the female lies on her side, and by rapidly working her tail to and fro, fans up the gravel until she gradually sinks into a kind of trough, the male remaining near, and ready to give battle to any intruder. For this purpose his lower jaw is furnished at this period with an offensive weapon in the shape of cartilaginous hook-like process. The female, waited upon by the male, now deposits her eggs in the trough which she has constructed; these are fertilised by the male, and subsequently covered by gravel to some feet in depth, the whole forming a redd. But although each female fish is provided with many hundreds of eggs, the proportion of such as are hatched, or ever arrive at maturity, is very small, being computed at one in nineteen. For, as might be anticipated, eggs deposited in running streams are very liable to escape the fertilising influences of the milt, and to be carried away by the current, or overwhelmed in mud; some become uncovered, others are eaten by hungry fish in the vicinity. Even if safely deposited in suitable redds, they still have their enemies to contend with: not only may floods prematurely sweep everything away, but during the continuance of such, spawning fish are unable to avail themselves of their usual breeding-grounds, as they are too deep in the water. They consequently may have to drop their eggs in the stream, where they will become lost or covered with mud, or else push higher up to where there will be more chance of their redd being left uncovered, and the ova perishing from drought when the floods subside; while severe seasons of drought may occasion most disastrous results. Irrespective of the season, the eggs have numerous water enemies, as the fresh-water shrimp, the larva of the May-fly, and even some birds, as the dabchick, ducks and swans, while the vole or water-rat joins in their destruction.

ARTIFICIAL SALMON AND TROUT CULTURE.

With such a large mortality among the eggs of the salmonidæ left to hatch in our rivers and streams, it became obvious that a great gain would probably accrue were the ova collected and hatched artificially in properly constructed houses, where an uniform temperature would be maintained and their enemies be kept at bay. In this position the artificial collection and fertilisation of eggs became one of the chief objects of the fish culturist, and the views of Dom Pinchin and Jacobi, already referred to, had an additional value.

One, if not the first, experimenter in Great Britain was Mr. Shaw of Drumlanrig, who, in 1836, collected salmon ova from the natural spawning-beds and hatched it artificially; and in January 1837 captured a male and female salmon in the Nith, pressed from them roe and milt, which he deposited in beds prepared for the purpose, and here he raised the fry. In 1842 two fishermen in a valley in the Vosges, named Remy and Gehin, again ascertained how fish naturally spawned, distinctly showing how it was possible to restock impoverished fisheries, and increase the fish-supply in almost any piece of water. Their discoveries would possibly have led to but little result, had it not been that, in 1848, M. de Quatrefages advocated, before the Academy of Science at Paris, on theoretical grounds, the artificial propagation of fish, and this brought to notice the discovery of the two Vosges fishermen. After prominent attention had been attracted to the subject, especially by M. Coste in France, and Messrs. Frank Buckland and Francis Francis in England, establishments for the artificial propagation and dissemination of fish sprang into existence in many quarters. Some succumbed after ephemeral careers, while a few flourished, and still continue to do so. By far the most important at the present time is Sir James Gibson-Maitland's Howietoun establishment near Stirling, from the breeding-ponds of which upwards of 156 gallons of trout and charr eggs were collected last year, while over a million fry, besides 2,900,000 eyed ova, were distributed. A model of this establishment is in the Exhibition. In some countries this direct means of increasing the food supply has been deemed worthy of Government aid and support; in others, as in the United Kingdom, it is left to the unaided enterprise and exertion of private individuals and local societies. In 1848 a labourer in Norway, being obliged to keep at home with a bad leg, used to pass his time by going to the river-side to catch the fish. Observing how the trout spawned, he, assisted by his wife, obtained a pair of fish, and expressed the milt and ova into water, and then placed such in sheltered spots in streams where no trout previously existed. Subsequently the eggs hatched and did well.

FISH HATCHING, REARING, AND BREEDING ESTABLISHMENTS.

In selecting water for a fish, or rather trout-cultural, establishment, considerable care is necessary, or irreparable mischief may occur. For a cessation of the supply when the weather is hot may be disastrous to the young fish; and, similarly, a freshet may do great or even irremediable mischief, unless suitable provision for such an occurrence has been made. Consequently, the intending fish-culturist has to be careful to examine the proposed locality as to whether the water supply during the hottest and driest period of the year would be sufficient for his wants, because its value to him is only in proportion to the supply at this time. Likewise, the heat of the water should be investigated at the warmest period of the year, and a natural trout-stream be selected if possible; also the possibility of pollution obtaining access should be ascertained, but a moderate amount of lime or iron is not necessarily an obstruction. Spring water, having an even flow with a low temperature, as from 41° to 45°, and free from animal and vegetable life, is often most suited to the hatching of eggs, and also producing a hardy and firm-flaked young fish.

Having obtained suitable water in an eligible situation, the next consideration is how to construct the ponds, and in determining this, the aspect, soil and other local circumstances have to be taken into account. But there must be three main considerations: the hatching department, the nursery, and the establishment for those which in time are to supply the market, or be the progenitors of future broods. Water which suits one of these requirements is not always suitable to the other—that from hot and cold springs, being deficient in animal and vegetable life, may be well adapted to hatch ova in, but not to feed young or adult forms; while brook-water full of life, even if charged with sediment, will be suitable to the young and old fish, but not to eggs; and it is better to be more careful respecting the supply to the eggs and young than to the old fish, as the latter are not quite so sensitive to changes.

The various buildings and ponds are best kept as compact as possible, and should be securely locked against all except those who have business inside, while strangers should be invariably accompanied by some of the regular establishment. Unless the various places are strictly kept under lock and key, the experiments of hybridisation are liable to be interfered with, and their consequent value liable to doubt. The ponds are safest if constructed by excavation, as dams are always liable to accident, while they must not be too large ; and, if practicable, a fall at the head of each pond is desirable, but this must be constructed in accordance with the water supply, and if such is plentiful and cold, the shape is of little consequence. If the water is small in quantity and liable to become heated, the pond should be deep and narrow ; while it should be possible to draw off the water, in order to repair or clean the pond, or make any necessary alterations in the fish which it contains.

Spawning-beds may be constructed at the upper end of the breeding-pond, or head of a pond where breeding-fish are confined ; this consists of a narrow channel down which a good stream flows, and which should have a gravel bed ; this channel should lead down very gradually to the deepest part of the breeding-pond. In such channels the breeding-fish may be netted for the purpose of obtaining the spawn artificially. Mr. Ainsworth, in the United States of America, conceived the ingenious idea of setting the trout to spawn naturally, while he could secure the eggs by means of covering the bottom of the channel or race with fine wire-cloth screens, of about ten meshes to the inch, made of zinc or of galvanised or painted iron wire ; these wire screens forming the floor of wooden frames or trays, which fit into the width of these races, but being raised about a quarter of an inch above the gravel bed of the race, so as to ensure a good circulation from below as well as from above. A second set of wooden frames or trays, similarly fitting the entire width of the race, and having a coarse wire-screen forming its floor, is placed immediately above the frames just described; but the wire netting is about two or three meshes to the inch, sufficiently strong to sustain two inches in depth of coarse gravel from three-quarters to two inches in diameter, in order to permit the ova readily to pass through. These upper boxes have handles, in order to allow their being raised and removed every few days during the spawning season. The trout spawns into the coarse gravel on the upper tray, and as the mother fans up this gravel with her tail, as she naturally does after depositing her eggs, they become driven through the coarse wire-netting which forms the floor of the tray, and consequently drop into the one beneath, where the wire-netting flooring is too fine to allow them to pass. On the upper tray having been removed, the eggs are found in the lower tray and taken to the hatchery. Due to the rather considerable descent of the eggs to the lower tray, when a current of water ascends from below, it would seem not improbable that impregnation from the male would possibly be in a rather small percentage. Mr. A. S. Collins has improved upon Mr. Ainsworth's process by substituting an endless apron (plate I, figs. 1, 2, 3) in place of the fixed wire-cloth in the lower tray, and which passes over rollers at either end of the tray, and which has small wooden cross-bars placed transversely at intervals. These cross-bars are supported by, and, when the rollers are turned, slide upon an inch square strip of wood nailed to the inside of the tray. A similar strip, one inch above, supports the upper tray. The cross-bars keep the eggs from being carried down by the current, as well as maintaining the wire-cloth upon the full stretch. By using two bevelled cog-wheels the front roller can be turned by a handle. As the roller is turned forwards, the wire-cloth, forming the endless apron, moves with it, and the eggs, as they reach the end of the roller, fall off. In front of this roller a pan is placed, and receives the eggs as they fall, and the pan with the contained eggs can be removed at will. This prevents the necessity of even the hands being placed in the water, while the spawning fish are not disturbed.

At the intake of the fish-ponds a gate must exist, permitting the water to be entirely shut off should such a necessity arise; while the outlet must be of sufficient dimensions to allow the passage of all the water of the highest possible flood height, making great allowance for the clogging of the screens, or even a wide channel may be advisable, should there be danger of too great a rush of water. Some prefer planks as the best material for forming the inlets and outlets, others use stone or bricks laid in cement.

For the purpose of cutting off the fish in a pond from obtaining access to the stream above or below, screens are necessary, and which are generally constructed of copper or galvanised iron, having very small apertures, and which are securely fixed into the frames, which completely fill the channel of the outlet or intake, especial care being taken that it reaches to the bottom. Livingston Stone recommends 18 threads to the inch for the smallest fry, 4 threads to the inch for yearlings, and 2 to the inch for two-year olds. To obviate clogging of the screens from descending debris, a frame may be built out in front of the screen.

Irrespective of the ponds constructed for the reception of the fish, buildings will be necessary for the hatching and rearing of the eggs, unless they are left incubating in boxes in the open waters. The water supply is a very important consideration; that from stagnant ponds, boggy grounds, or marshes is evidently unsuitable, but each case has to be decided by local circumstances as already remarked. Some prefer obtaining that for the supply of the hatching-house from a clear lake from which a stream flows, which should be taken a short distance below its outlet and with an intervening rapid, which charges it with air. From such sources the amount and also the temperatures are comparatively even, and sediment and other deleterious influences are generally absent. Or brooks supplied by springs, which are of sufficient capacity to ensure a constant supply at a moderate temperature, even during the hottest day. If, however, this water is to be used for young fish, after the absorption of the umbilical sac or yolk, it should previously flow for a long distance over an open channel. Pure spring-water possesses many advantages; thus, at Howietoun, it is obtained at about a mile from the hatchery, to which it is led by underground pipes, having settling ponds every four hundred yards, and this obviates the necessity of employing filters, while the temperature of the water is very equable. River water, if clear, may be employed, but it is liable to drought as well as to flood, and often carries down ice in winter, or leaves, sticks, and other debris.

The site of the hatching-house should be selected near to where a good head of water may be obtained, while the size of the building must correspond to the amount of work which it is proposed to carry on within. The walls should, if possible, be very substantial, and a considerable slope should be present from the upper to the lower end, in order that the hatching-troughs may be placed in a stair-like sequence (plate I, fig. 6), the front one being slightly below that from which it receives its supply of water. In very cold climates it is advised that, in order to prevent the formation of ice, the house may be constructed partially underground or on the lee of a bank. As a rule, the room keeps comparatively warm and of a much higher temperature than the outer air.

The supply reservoir is most important, and should be constructed of the most durable material and best workmanship. All descriptions of dirt and debris should be kept out, light likewise should be excluded. In some places it is necessary to dam streams in order to obtain the requisite head of water; but there must always be a danger, especially if the dam exceeds two feet in height, of its giving way.

The conduit along which water is conducted from the supply reservoir to the hatching-house has to be especially considered, its duties being most responsible, as should it fail, the death of all the ova may result. Some fish-culturists recommend that it should be capable of carrying twice or even thrice the amount required, in order that the water may be aërated while in transit; while it may be constructed of wood charred along the inside, in order to prevent the generation of fungus there. The conduit may be open or covered at the top, and, if the latter, the intake had better be guarded by a screen, to prevent the intrusion of any foreign bodies which might choke the pipe. Owing to the injury caused to the eggs of salmonidæ by deposits of sediment, which, if left undisturbed, kills the embryo, or causes it to be weak or even deformed if hatched, great attention has generally to be paid to the filtering of the water. Some springs, such as the one employed at Howietoun, are sufficiently clear for filters being unnecessary; but in others, although apparently clear, still sediment is being deposited, and which, if it does not destroy the embryo, is considered to often occasion many deformities.

Where filtering is required the water from the conduit may be conveyed into a tank termed the settling tank and where the heavier dirt subsides. A conduit conveys water from the upper part of this tank to the hatching house where filtering can be carried on in several ways. Some make the water pass through a bed of gravel, but usually flannel filters are preferred, and these consist of flannel fitted into a light wooden frame-work which slides into grooves placed for the purpose along the inside of the filtering-tank, and which slide is at an angle of about 45,° having the lower end up stream; should the filtering trough be about 18 inches deep, the top of the filter ought not to be above 15 or 16 inches in height or it will occasion a slight heading of the water; care must be taken to keep these filters clean, changing them when necessary. Having passed through as many filters as are deemed requisite, a communication some inches below the surface leads the water into the head or water-supply trough which lies side by side and goes across the hatching-house, and at right angles are the hatching-troughs, usually placed in pairs, with an intermediate space to allow the attendant sufficient room to obtain access to the eggs. Water passes from this distributing trough into the upper of the hatching troughs, which latter are long and shallow, being from 6 to 8 inches deep, and from 8 to 12 wide, having a short portion at the upper end, where the water enters, screened off by a piece of perforated wire screen, and a similar screen at the lower end; these should be carefully fitted in to prevent fry escaping or anything but water passing. These troughs may be constructed of various materials, as slate, stone, pottery or wood; and should the latter be selected, odorous forms must be excluded, being fatal both to eggs and young fry. The cheapest and apparently best material is wood thoroughly charred, which process renders it free from fungus, besides having a purifying effect on the water. These troughs are arranged in flights so that a fall exists between one trough and the next, as shown in Slack's hatching grill (see plate I., fig. 6). Should the water be deficient in aëration short ones should be employed. A light, loose, wooden cover should be furnished for each, in order to exclude light and enemies to the ova and fry.

When artificial hatching of the eggs of the salmonidæ was first commenced, they were almost invariably laid down upon clean gravel, a layer of which, about 1 inch to 1½ inch in depth, was laid evenly at the bottom of each trough, the size selected being that of a very small pea or even slightly less. The gravel was sifted to the required size, washed and even boiled.

Glass grilles, although expensive, are generally approved of, more especially when the questions of space and cost are less material than the raising of strong and healthy fry. They may be employed in troughs composed of any of the substances already alluded to, and are well adapted to those made of carbonised wood. A wooden frame (see plate II., fig. 8, illustrating the Howietoun plan, and the method of fixing the glass tubes, fig. 9) may be constructed to fit that portion of the trough where the eggs are to be hatched, and glass rods or tubes are fixed across the under surface of the entire length of this frame, which may be done by means of a strip of perforated galvanised network. A ledge of wood an inch deep prevents this frame of glass grilles sinking to the bottom of the trough, while a wooden catch keeps it from rising above the desired level, and this secures a current below the grilles as well as one above them. The eggs are distributed, by means of a feather along these rows of grilles, and any that are dead are immediately observable, irrespective of which the stream does not congregate them together in masses as is always to be feared unless mechanical obstacles intervene.

Livingston Stone remarks that simple charcoal or carbonised troughs are equally as efficacious as grilles and infinitely more economical. He considers the first to be the thing for business, and the second more suitable to the rich man's experiments.

Many other descriptions of hatching apparatus for eggs of salmonidæ have been employed with success;[1] some of them likewise effect a great economy in space, but it generally occurs that, if the amount of water is curtailed, weak young are the result. At Howietoun, where the average temperature of the water is from 41° to 45° Fah., Sir J. Gibson-Maitland is in favour of a supply of not less than ten gallons a minute to every 100,000 trout eggs, while, by increasing the flow during the latter stages of incubation, fully 99 per cent. can be hatched, and very nearly as successful results with the eggs of the salmon, the difference being probably due to the difficulty of obtaining perfect impregnation in the case of ova taken from wild fish.

The following apparatus for hatching the ova of Salmonidæ is exhibited at the Fisheries Exhibition by Mr. Oldham Chambers, its inventor. It consists (see plate IV., fig. 26) of a long box 6 feet or more in length, 18 inches in width, and 12 inches in depth.

The eggs are deposited on perforated zinc trays 15 inches long, with about two inches of water over each. The supply-pipe is fixed under the bottom of the box, and has T pieces inserted in it under the centre of each tray, in which are screwed rose-jets level with the inside bottom of the box : this causes a complete circulation and distribution of the water before it reaches the eggs. The inventor claims economy in construction, as well as in the quantity of water used; and as it is upon the underflow principle, great cleanliness to the eggs is the result. The whole of the wood work is coated with a silicated preparation which entirely prevents any fungoid growth.

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[1] Metal substances, unless sufficiently coated to prevent rust or absorption from their surfaces, are unsuitable.

In the United States, Canada, &c., wire trays are extensively used for hatching fish eggs, these may be fixed to light wooden frames which fit the troughs, and are coated with asphalt varnish in order to prevent fungus growing on the wood or the wire from rusting. These trays may be in a single, double, treble, or even four tiers. In the United States Section are several models, to some of which I purpose referring.

GARLICK'S HATCHING-BOX patented in 1851.—A simple trough, of which the bottom is covered with pebbles, on which the eggs remain until hatched, the water entering through a spout above and passing out through an opening protected by wire-cloth at the lower end.

Length, 18 inches ; width, 9 inches ; depth, 6½ inches.

This is the first form of hatching apparatus used in the United States. It was adopted by Dr. Garlick, who may justly be called the father of fish-culture in America. Though simple, the results obtained by its use were very satisfactory.

ATKIN'S HATCHING-CRATE.—A frame of metal and wood with hinged cover, which incloses a nest of 9 egg-trays.

Length, 12 inches ; width, 12 inches ; depth, 7 inches.

This crate is used chiefly for hatching eggs of the salmonidæ. The trays are provided with corner strips of wood, which separate them slightly from each other to allow free circulation of water, though the spaces are not large enough to allow the escape of eggs. These crates can be placed either in the open stream or in ordinary troughs.

A section is shown of the Clark hatching-trough, invented in 1874. It is supported on wooden standards, showing two compartments complete. Each compartment contains a hatching-box, the bottom of which is perforated with holes and raised slightly above the bottom of the trough by means of wooden standards to allow the escape of water from beneath. Each hatching-box contains 12 trays of wire-cloth, on which the eggs remain during their development. A Clark trough usually contains 10 to 20 compartments, each being separated from the adjoining one by means of a partition, which is notched at the centre, and provided with a tin spout for conducting the water. The trough is placed at a slight incline, and the water, entering the first compartment, passes down through the trays of eggs out at the bottom of the hatching-box and up around its sides and ends on its way to the second compartment, all of the water passing through each box before it finally leaves the trough.

HOLTON HATCHING-BOX, invented in 1873, consists of a square wooden box, with a tin bottom sloping downward and inward toward the centre, where the inflow opening is situated. Just above this is a rectangular piece of tin, against which the water impinges as it enters, thus being deflected toward the sides. The box is provided with eleven trays of wire-cloth, each separated from the other by the wooden frame to which it is attached.

Eighteen inches square and 12 inches deep; outside measurement, including base and waste-trough, 22 inches square and 20 inches deep.

The water enters the buckets through a tube which extends from the top around the side to the inflow opening at the centre of the bottom, from which it passes up through the trays of eggs into a trough at the top which conducts it to the outflow spout.

This is one of the first forms of apparatus by which an upward current of water was utilized, and the inventor claimed for it many advantages over other systems. These boxes are often so arranged that the water passes through a series of 20 or more, each box being a trifle lower than the preceding one and the outflow of the first communicating with the feed-pipe of the second.

FERGUSON HATCHING-JAR (plate III., fig. 20), invented in 1876, consists of a cylindrical jar of glass, with a contraction near the base, which serves as a support to the 7 wire-cloth egg-trays which it contains. It has two circular openings on opposite sides; one at the bottom for admitting the water, which passes upward through the eggs and out through the second opening, which is situated at the top. Height, 12 inches; diameter, 8 inches.

For economy of water, the outflow-opening of one jar is connected with the inflow-pipe of the next by means of rubber tubing. By this means the water passes through an entire series of jars before it finally escapes. The jar is used chiefly for hatching eggs of the salmonidæ. It holds about four thousand salmon eggs or six thousand trout eggs.

BUCKSPORT HATCHING-TROUGH.—This is a section of a hatching-trough showing two compartments complete, with nests of trays. Each compartment contains a frame which is closed when in use, but can be opened for convenience in removing them.

Length, 31 inches; width, 15 inches; depth, 17 inches.

Employed by Charles G. Atkins, of Bucksport, Me., for hatching eggs of various species of salmonidæ.

The method employed by the Canadian Commissioner, Mr. Wilmot, differs in several details from the plans pursued in other countries, the varnished perforated tin trays which are used combining either to form a vehicle for conveying or else for hatching ova. When for the first purpose, they are covered with flannel or other suitable material; but if for hatching purposes they have their sides and bottom perforated. These tin trays are painted with parafin varnish in order to prevent rust, and this is yearly renewed; their dimensions are 10 × 15 inches long, with a partition along the centre.

The trays are placed in the usual manner inside the hatching troughs, resting upon a wooden edge half an inch high, which prevents their reaching the floor of the trough, and thus permits a current of water passing below as well as through and over them. If necessary, these trays may be placed one above another in the troughs, thus economising space. Filters are not generally employed; but should any deposit be observed, the water at the inlet is shut off, and a plug removed from an opening at the lower end of the trough by which means the eggs are run dry; then by using a common watering-can the dirt is washed off and subsides through the perforated bottom of the tray, and becomes carried away by the underflow through the plug-hole already referred to. The plug-hole is surrounded by a circular screen of perforated zinc, this form being found most useful in preventing young fish from being carried by the current against this construction, and having their yolk sac forced inside the perforated orifices. The overflow pipe being thus unguarded, the water from the trough is received into a tin bucket, the upper half of which has perforated sides, in order to permit an easy escape of the water descending with it, while across its centre is a removable tray which breaks the force of the current, while the avelings obtain access into the space below it. Existing at the bottom of this bucket is an orifice secured by a cork, so that when opened it allows the imprisoned young fish to be removed, without handling, or injury of any kind, into any suitable place.

The eggs having been deposited in the trays, troughs, or whatever mode it has been decided to adopt, are left in the hatching-house to develop into young fish. They have to be kept in suitable water and left to mature, the following sources of danger being guarded against:—Sediment in the water, and living foes which have already been treated of; also fungi of which there exist two principal forms: the first has to be kept at bay by means of charring the wood, for, if it once commences, all the eggs will be lost, or the young when hatched will be sickly and worthless; it sometimes shows itself when the cause producing it is obscure. Dirty water will not invariably bring it, nor clean water keep it away. If eggs coalesce into masses they should be carefully examined, and the presence of fine threads floating among them shows fungus. Increasing current of water and shutting out all light are the best means for retarding its progress. The second form of fungus, known as byssus, is a product of decaying matter in the water, and is found in eggs which have perished and began to putrefy. It develops long tendrils, which it spreads out in every direction and causes the death of the eggs so touched; this renders it necessary to pick over the eggs, carefully removing such as are of a dull white, for they should not be allowed to remain above twenty-four hours in the troughs for fear of contaminating those in their vicinity.

There are other reasons which account for the dead eggs, thus such may be due to want of impregnation, which, although usually commencing to be seen a few days after being placed in the troughs, may not be observed for several weeks. Several plans are in use for removing dead eggs: as a bulb-syringe, or a miniature spoon, tweezers, or nippers made of fine steel wire. The time required for hatching trout eggs has been found by Seth Green, in the United States, to be that at 50° Fahr. they take 50 days; and every degree warmer or colder makes five days' difference in time, the warmer shortening, the colder lengthening it; also, if fish are hatched in 50 days, the yolk sac remains 30 more: if hatched in 70 days, the sac remains 45 more.

The normal period eggs take hatching is found when the water is kept at about 44·10 degrees to be as follows at Howietoun:—*Salmo fario*, 71 days; *S. levenensis*, 72; *S. fontinalis*, 73; *S. levenensis*, crossed by *S. salar*, 75; and *S. salar*, 77 days. But, as already observed, lowering temperature delays hatching, increasing it hastens such on.

ON OBTAINING OVA OF SALMONIDÆ.

There are three sources from whence the necessary supply of ova can be obtained, and these are either from fish living in a wild condition, robbing the redds in the rivers or streams, or else from such (as trout or charr) as are purposely kept in breeding ponds.

At Howietoun breeding fish are fed with clams, commencing in January and during the spring, in order to assist in developing the eggs, which commence ripening about October. If eggs are taken from late fish a whole summer is nearly gone before the yolk sac is absorbed, or a year all but lost. When clams are not to be obtained mussels, (*Mytilus*), may be employed, but they cause much additional labour in extracting the mollusc. They are scalded for this purpose.

The mode of spawning fish, similarly to every other occupation, requires time in learning, while the experienced and careful fish-culturist will obtain a larger supply of eggs from the ripe fish, and such will likewise be in a more favourable condition for hatching, than will an inexperienced or careless manipulator. Prior to the spawning season care should be taken that everything is in an efficient state and good working condition. As the spawning season comes on the colours of the male fish become brighter; the lower jaw of the male of the salmon and trout becomes furnished at its extremity with a cartilaginous hook; the proportion of the head to that of the body becomes apparently longer, and they commence to decline food. The female becomes larger, and distended with spawn, but does not assume such bright colours as the male, although like him she goes off her feed.

Salmon for breeding purposes must be captured in their natural haunts, which is often a proceeding of no little difficulty. If they have ascended small streams they may generally be readily obtained, but this is not so easy upon fords of larger rivers. The local difficulties and the exact period for commencing work are subjects upon which the best local advice should be acted upon; but even then sudden storms and atmospheric changes may render abortive the best laid plans. It has been observed that in this family, when in a wild state, the number of male fish captured in the breeding season is largely in excess of the females; whereas in breeding ponds, it appears among trout, as if the males do not live so long as those of the other sex, and consequently the females are the most numerous.

Salmon and trout generally resort to their breeding-grounds a few weeks prior to depositing their eggs, which process is usually completed between November and March.

Having captured what appears to be a breeding salmon in a suitable condition—such may be ascertained by exercising a little pressure along the abdomen, when milt from the male or some ova from the female will be extruded—occasionally in the latter sex a little coaxing is necessary, as she will not always yield it at the first pressure. If the ova are not quite ripe, the abdomen, though distended, will be felt hard and somewhat unyielding, whereas in ripe fish it is soft, and the ova can be felt moving under the pressure of the hand. It may be that ripe females are present but no males, and consequently it becomes necessary to consider whether females in this condition can be retained so for any length of time; in some localities they may be placed in small contiguous pools, or tubs, or such like conveniences, or even secured by means of a cord being tied around the tail. The same proceeding may be adopted for the male fish, while it is always desirable to retain one or two of this latter sex in reserve, or milt may be kept closely corked in a phial for several days until required, it having been found to be fertile up to the sixth day. At Howietoun it has been shown that among trout and charr the extrusion of milt or ova can be retarded by placing the fish in a smooth box through which a stream of water flows, thus apparently demonstrating that external pressure is necessary, and from a rough surface; in short, that mechanical assistance is required for the extrusion of the eggs. The apparatus for spawning fish is not very extensive:—A shallow tin or earthenware pan for receiving the eggs and milt, the latter being furnished with a de-pressed spout for the purpose of passing them into the tin carrying-can, this latter having a perforated lid. A jug for clean water is likewise required, and a dry cloth is useful for the purpose of securely holding the fish. A large salmon is a difficult object to keep steady, often requiring as many as three persons : some operators prefer to grasp the head of the fish between their knees.

The fish is held with its body somewhat sideways, its tail downwards, and its abdomen slightly turned towards the operator (plate IV., fig. 21), while the pan to receive the eggs is placed as near as possible to the vent. Gentle pressure is exercised on the fish, commencing from the ventral fins and passing downwards towards the vent. Should the eggs not appear it does not always follow that the fish is not ripe, and operations on it should be suspended for a few minutes, when it will sometimes prove more accommodating. If, however, it is not quite ripe it may be kept for a day or two, or even more, in a suitable place in order to allow the eggs to mature ; but force is never to be employed ; for if by such means immature eggs are extruded the produce will be valueless, and the old fish perhaps mortally injured. Having obtained ova or milt the fish should be gently retransferred to the water, and no deleterious consequences follow the operation.

ON THE TREATMENT OF OVA.

There are two processes, either of which may be adopted when spawning winter fish, the moist or water plan, and the dry, so termed because, in the first or old process, some water is placed in the pan which receives the eggs as pressed from the fish ; for fish culturists used to consider that if the eggs and milt were mixed together in water the operator would be more closely following the natural process. The dry process, on the other hand, dispenses with water, the eggs being pressed directly into a dry pan ; over these eggs the milt of the male is distributed, and the pan is now tilted at its ends and gently shaken ; after giving the eggs and milt time to mix, water is poured in to the depth of two or three inches, and stirred with the hand, and allowed to stand until the ova harden or "frees," as the Americans term it, a period of from ¼ to ¾ of an hour, according to temperature, taking longest in cold water. For the eggs as extruded are soft, and adhere to whatever they come in contact with, evidently consequent upon the absorption which is going on through the micropyle. Water becomes gradually imbibed, and when the interspace between the outer and inner coat is filled, absorption, as a consequence, ceases, the egg no longer adheres to surrounding objects but frees itself, and is a hard, round elastic body. As soon as this is accomplished, more clean water is gently poured over the eggs, and when it is no longer discoloured they can be transferred from the receiving to the carrying-can, which transferring, however, should not take place too soon, while the eggs must be properly cleansed, or some effete milt will remain and cause injury to the eggs in the hatching boxes. The most fertilising milt appears to be such as is of medium consistence, neither very thin nor very thick.

Under the moist or water process the average success in fertilising eggs probably rarely exceeded fifty or sixty per cent., while it frequently was much less. M. Vrassky, in 1856, inaugurated the dry process for reasons already detailed, since which as much as ninety-five per cent. of successful eggs have been of no uncommon occurrence. When the labour of separating dead eggs in the incubating boxes is considered, and which has to be carefully done and each separately removed, it is a subject of great consequence even on the score of labour alone.

The variation in the colour of the eggs of trout can hardly be deemed hereditary, or due to the food which they consume, or to the colour of the flesh of the parents, as some observers consider; for the Lochleven breed, reared in Sir J. Gibson-Maitland's ponds, of the same age, fed on the same food, and descended from the same stock, show pink, coral, yellow or white eggs.

The hardened eggs are now transferred to the carrying-can in the proportion of one third eggs to two-thirds water, and the whole removed to the incubating-house, where they are gently spread and distributed with the aid of a feather over the hatching-troughs. Trout eggs are similarly treated to those of the salmon, but are more readily handled, owing to their smaller size.

Grayling ova are more difficult to procure than those of the trout, owing to the brief period during which these fishes spawn, which generally commences about March or April; the rivers where they reside are always liable to be in flood, and consequently no delay should occur in securing ova as soon as possible after the fish have resorted to the shallows to breed.

Other things being equal, the shorter the distance and smoother the conveyance between the spawning ground and the troughs, the greater are the probabilities of the eggs hatching in a satisfactory manner and producing a robust race of fish.

At the McCloud river, for transporting *S. quinnat* eggs across the North American continent, they were packed in moss, which on arrival is washed and twice picked over very carefully. The outside packing is of sawdust, hay, or dried ferns; a layer of moss and one thickness of mosquito net are first placed for the eggs to rest on; and so all the way up.

Ova have been transported long distances with complete success, as from Europe to the Australian colonies, Canada and the United States, and likewise from the last two countries to Europe. In the year 1854 Mr. Youl's attention was first directed to this subject, and he came to the conclusion that, in order to convey salmon to Tasmania, the ova or small fry alone could be successfully carried through the tropics; but it was not until 1862 that a conclusive experiment was undertaken. Having seen in Paris moss used for packing salmon ova, and in which they travelled short distances with perfect safety after their eyes were developed, on March 4th, 1862, Mr. Youl packed some in moss within a wooden box, made of inch pine, and having its sides perforated: this he deposited in the centre of the ice in a vessel in which an experiment was being carried on. Contrary winds and misfortunes were met with, and on May 8th, the ice being very low, the box of ova came into sight, and nineteen living ova were found surviving. Nine days subsequently the ice had all melted, and the ova perished seventy-four days after leaving London. Experiments were tried in the Wenham Lake Ice-vaults in London, when it was conclusively shown that the hatching of salmon ova could be retarded to the 144th day. Since then eggs have been safely conveyed in ice to Tasmania and elsewhere; and the possibility of retarding hatching, even to so late as the 148th day, has been proved. This retardation of hatching has also been employed for the purpose of delaying the incubation of some forms of eggs, until sufficient room exists in the hatching-house for their reception, and thus several relays may be successively hatched in one operation.

Experiments were made in Austria (*Ö-U. Fischerei-Zeitung*, Vienna, 1880) by Max von dem Borne, respecting dry fertilisation of salmon ova (or such as had not been brought at all into contact with water), and their development thereby delayed, could be more readily transported than if brought into contact before their journey, and transported during the first condition of embryonic subdivision. Some salmon eggs and milt were transmitted from Basle together in a hog's bladder without the addition of any water. This was done twice, and with them at the same time a number of eggs treated and hatched in the ordinary manner. The journey lasted three days, and the temperature was high, in spite of which the dry packed eggs both times arrived in good condition and were of a beautiful red, while the eggs treated in the ordinary manner were almost all dead and of a very pale colour.

The best time at which to transport eggs is undoubtedly after the eye has become visible, when they may be sent in damp moss. At Huningue the mode used to be to take a wide-mouthed bottle at the bottom of which was placed thin layers of damp moss, above this a thick layer of eggs. Again a stratum of moss followed by another of eggs, and so on up to the top of the bottle, the neck of which was filled with damp moss. The bottle was tied over with a cover of paper full of fine holes in order to admit the air. One or more bottles were then closely packed in a box with damp moss, while an outer case, having an inside lining of wet moss, received the smaller box. In warm weather a little ice was mixed with the moss. Grayling eggs hatch so rapidly—as within three or four days after the appearance of the eyes in the eggs—that they are transported with the greatest difficulty.

Several plans for transporting the eggs of Salmonidæ are exhibited in the United States Section, and the plans may be summed up as defined by Livingston Stone, that they do not require much water but plenty of air, consequently, when hatched in wet moss, these conditions are supplied.

GREEN'S TRANSPORTATION-BOX (Model).—A wooden box containing eight cotton-flannel trays for holding the eggs.

Nine and one-half inches square; height, 11 inches.

Trays, 7 inches square, inside measurement.

In imitation of Clark's transportation box.

ATKIN'S TRANSPORTATION BOX (plate 4, fig. 25)—A wooden box containing four smaller boxes, in each of which 15,000 salmon eggs are placed upon layers of muslin.

The space between the larger and smaller boxes is filled with hay to prevent an unhealthy change of temperature, and the layers of eggs are separated from each other by wet moss. Eggs packed in this way can be sent several thousand miles with very satisfactory results.

MODEL OF ANNIN'S EGG-TRANSPORTATION BOX.—This apparatus consists of an outer case which contains a smaller one, surrounded by sawdust, to prevent loss of eggs from sudden change of temperature. The inner case is provided with eight trays, with cotton-flannel bottoms, for holding the eggs. The tops and bottoms of both the inner and outer boxes have small openings, by means of which the eggs can be kept moist, the water being thrown upon the top of the box and allowed to trickle through the eggs on its way to the bottom. There is a small ice-chamber between the tops of the outer and inner boxes, and the bottom of the outer box is provided with wooden strips, to prevent its coming in contact with the surface on which it rests, which would prevent drainage. Boxes of this pattern have been used by Mr. Annin for sending eggs of the brook-trout to Europe.

MATHER'S TRANSPORTATION CRATE.—A wooden box with a grating of the same material separating it into two compartments, the upper serving as an ice-chamber, while the lower contains thirteen cotton-flannel egg-trays. The ends of the four pieces which compose the frame of the tray extend an inch beyond the point of intersection to form an air-chamber on each of the four sides of the box, thus giving a free circulation. There is also a slight space between each tray, and a larger one at the bottom. A box similar to this one was used in sending salmon-eggs from America to Europe.

On opening a package of fish eggs, should they be packed in moss, the bulb of a thermometer ought to be inserted under several layers of eggs, being careful to admit as little air as possible, and should be left there covered over for about a quarter of an hour. Should the temperature be within 6° Fahr. of that of the water in the hatching-troughs, the eggs may be deposited in these; but should the difference be 6° higher or lower, the carrying-box should be drenched with water of intermediate degrees, so that the temperature may be gradually assimilated, and not until this is completed should the eggs be transferred to the hatching-troughs. If there is not sufficient time to unpack all the eggs on receipt, the carrying-boxes should be placed in a room of uniform temperature, but they should never stand in water. Eggs are not injured by exposure to air, provided they do not become dry, or warm, or freeze.

When the eggs are about to hatch they require considerable attention, for in some the process of emerging from the shell is more easily gone through than it is in others. Generally, if the eggs are small, it has been observed that the young emerge tail first, while in the larger ova they split down the line of the back, and the fish may frequently be seen with its head covered by a portion of the shell; this occasionally causes suffocation. Some come forth strong and lively, others weak and listless; and these weakly ones have not the chance of growing to a fine healthy trout that the more vigorous ones have. Occasionally a slight assistance is necessary, in order to assist the embryo from its shell. As the young begin to move about, care may be necessary that they do not congregate in too large numbers in one place: to prevent this, some fish-culturists insert screens. During the period the yolk sac remains unabsorbed, and which varies from three weeks to three months after hatching, according to the temperature of the water, these young fish, which are termed "Alevins," carry their food about with them, and are not difficult to keep alive if proper supervision is exercised.

TREATMENT OF YOUNG FISH.

While the hatching process is going on, the free use of the watering-can has been recommended to clear the bed of the trough of the numerous egg-shells. After a few days the Alevins seek dark places for hiding in. Some fish-culturists keep them in very shallow water with a strong ripple, others employ deeper water with a slow current. Now they seek every crevice, and push into any cavity they can find, and care has to be taken that no spot exists where they are able to find a hiding-place which will prove fatal to their existence. After the young fish have absorbed about half the yolk sac, they appear to require more air and follow the stream upwards, and great vigilance is necessary to see that they do not escape. But they avoid water which is disturbed, and doing this with a feather, or pouring in water, often has the desired effect of driving them elsewhere to seek a quieter spot. Alevins live a long time in water which is unchanged and has no current passing through, consequently at this period they can be transported with comparative ease.

At Howietoun the Alevins are fed for about a week or fortnight before the yolk is entirely absorbed; the food given being the yolk of nine eggs to one pound of beef, these are pounded together and pressed through a fine sieve.

After the umbilical sac has been absorbed is perhaps the most dangerous period for these fish, for up to then they have subsisted upon its contents; but the period has now arrived that means have to be adopted to feed these delicate little creatures until they are sufficiently grown to be able to feed themselves. After a short time the little fish commence attempting to spring out of the trough, demonstrating that they ought to be turned out into larger pieces of water. Now the young begin to seek subsistence for themselves, and instead of congregating appear more desirous to separate one from another; they commence to raise themselves off the ground and balance themselves in the water, as well as to take any food which is offered. When they begin feeding, they may have a meal twice on the second day, and subsequently four times daily for a couple of months, when by degrees the feeding times may be reduced to twice daily until the cold season sets in. These very young fish can only take the finest particles of food, and different fish-culturists have each their own views on the subject. Livingston Stone observes that young living perch and suckers would probably make the best possible food for the very young trout-fry, and could be obtained in vast quantities; but if artificial food is employed, he advises liver, and curd made from sour milk, mixed in about equal proportions, or, still better, with two parts liver and one part curds. The curd should be made as fine grained and moist as possible; while the liver should be reduced to the smallest possible particles, for which purpose he recommends grating the liver on a tin lemon or cheese-grater which has small holes not above one-tenth of an inch in diameter. This may be placed on a fine screen and thus fall through to the fish below. Or yolk of eggs boiled half-an-hour, and subsequently finely powdered, but it rapidly becomes stale if unconsumed. Curds or eggs alone will not be good food for the young fish, but liver may be employed without any addition. Their digestive powers are great, and there is more fear of over than of under-feeding the fish; but should the food be in too large pieces there is danger of their being choked, but care must be taken that no refuse food remains to putrefy. Professor Haack advises that when natural food is not present, the larvæ of gnats, and also of the Daphnia, Cyclops, &c., should be employed, and which can be skimmed off stagnant waters, as ditches, pools, &c., with a fine muslin skimmer. At Heningen, two children, at work twice a day, obtained sufficient to feed from twenty to thirty thousand young fish.

Unless the hatching-troughs are very large, the young fish will require thinning out, or they will be in excess of the necessary space. The fry will divide into two sets, the larger taking the best locality and driving off the weaker ones, which will herd by themselves, and, unless specially attended to, will not grow at the same rate as their stronger relatives. If very weak, they may be pressed against the lower screen. Should they commence dying, due to putrescence of the water consequent upon the subsidence of unconsumed food to the bottom, the best remedy is common earth, as shown by Livingston Stone.

If the fry are removed from the hatching-troughs, they should be located where there is a sufficient supply of fresh water and shade under which they can remain, and kept from foes and fungi. This can be effected in a rearing-box, ponds, or other suitable locality. In some places, so soon as the young fish have absorbed the yolk sac, they are turned into suitable spots in order to stock rivers; but it occasionally happens that the desired results are not fulfilled so completely as was anticipated. The fact possibly may be that the young were of weakly constitutions, and turning such fish into streams might perhaps only end in their dying there, or being eaten by their foes.

THE "THOROUGH" VASE (see plate 4, fig. 28), for the rearing of salmonidæ, as designed by Mr. Oldham Chambers, is to be seen in the Exhibition. It is circular in form, the water being admitted through a pipe passing round the inside of the vase about two inches under water; this pipe is pierced with holes at an angle of 45 degrees, the pressure of water gives a centrifugal motion to the current, thus causing the young fish to "head on" to the stream. As soon as the young fish have lost their umbilical sac, they are placed in the vase and fed with finely chopped liver, the peculiar motion of the water causes the food to be held in suspension longer than with most other forms of feeding apparatus.

The overflow passes through perforated zinc inserted in the bottom part of a tube, fixed in the centre of the vase to prevent a vortex, inside which is a standing waste-pipe, and, by lifting up the latter, the vase can be cleaned out in the space of two minutes, without endangering the lives of the fish, as they are all protected by the perforated zinc.

Another feature of great importance is the small amount of water consumed by the apparatus; a stream not larger than a pencil is sufficient to keep 10,000 fry alive in a vase two feet diameter for several months.

STOCKING PIECES OF WATER.

Should it be intended to stock pieces of water, Sir J. Gibson-Maitland observes that eyed eggs may be turned down into artificially and carefully constructed redds, scattered all over the district in close proximity to the best feeding grounds and ripples for the fry. Such absolute purity of the water flowing over the redds is not required for eyed ova as it is for the eggs prior to this period, still discoloured water should never be employed. It is also requisite that the redd be situated near a stream of less pure water, as the absence of fine particles, so necessary for the health of the embryo, is not satisfying to an active young trout of a few weeks old. A natural river temperature of 50° will, as a rule, produce ample food for the young fry. Prior to the absorption of the umbilical sac they should not be placed in ponds or muddy water. They will not bear much handling, but bear carriage very well: a 40-gallon tank being sufficient for the conveyance of about 15,000 which have been feeding for more than a month, except for very long journeys, when a supplementary small tank requires to be added, which altogether saves the necessity of handling the fry. They can be reared in small properly constructed ponds, and subsequently turned into deep water.

Pieces of water may be stocked with trout, for which purpose either eggs or young fish may be obtained from a breeding establishment. It is highly desirable, prior to receiving such, that a careful examination should be made that the nurseries do not contain their enemies, as bullheads (*Cottus gobio*), which will eat them as rapidly as it can find them. At the Howietoun fishery it is suggested that streams with sediment in the water, or a liability to floods, are unsuited for depositing ova, and fry are recommended instead.

The time necessary for preparing young trout for transport varies from three or four days in the case of yearlings, to as many weeks for large examples. The yearlings are sufficiently strong to find their own food, thus avoiding the principal cause of mortality among fry, which is starvation. They soon accommodate themselves to new pieces of water. Two-year-olds succeed best where coarse fish or large fish already exist in the water. It has been found that there is no difficulty in conveying trout in iced water for any journey not exceeding twenty-four hours. That unless the water which is to be stocked is of similar temperature, some loss will arise from inflammation of the gills; they are consequently carried best in cold weather.

Many different plans are in use for conveying fry from one locality to another, several of which will be found in the United States Section.

CLARK'S FISH-TRANSPORTATION CAN.—A cylindrical tin can with 20 circular trays of perforated tin.

Diameter, 6 inches; height, 9 inches.

The trays rest one upon the other, a tube which extends from the top to the bottom of the can passing through the centre of each. The water is introduced through this tube, passes to the bottom, and up through the eggs, on its way to the outlet near the top of the can. Each tray will accommodate one thousand salmon.

Stone's conical transportation-box is a model 12 inches high, 11 inches in diameter at its base, and 6 at its top. It is a truncated cone of tin, with a perforated cover, capable of holding ice for reducing the temperature of the water in the can.

This can is used in transporting of various species of salmonidæ. Its principal advantages are derived from its peculiar shape, which, according to the inventor, facilitates the aëration of water. Cans of similar shape with the cone produced into a long funnel-shaped cover are frequently used.

STILLWELL'S AËRATING PUMP.—A tin tube, the lower end of which is incased in perforated tin to prevent the fish from being drawn into it. The spout is also provided with a covering of perforated tin, and the water, which is forced through, is broken into a great number of minute streams or jets, thus giving complete aëration.

This pump is used in aërating the water in which fish are transported, when it is not convenient to procure a fresh supply. In aërating, the pump is inserted in the mouth of the can, and the water is pumped up and forced through the perforated tin spout, falling back again into the can.

Irrespective of growing young salmon or trout for turning out into suitable waters for their breeding, some at least may be kept in ponds for the purpose of obtaining their eggs, or placed in suitable rivers in order to supply the market with food.

Space will not suffer me to enter upon the varying character of the trout,—how he thrives in large pieces of water where food abounds, and in his turn delights the angler in streams, the cook in the kitchen, and the reveller at his feasts; while the water which suits him best is accurately laid down in works of natural history. For the same reason must be omitted how to protect these fish from their enemies, whether of the poacher or vermin tribes. The finest yearlings I have personally seen are those shown by the Marquis of Exeter at the present Fishery Exhibition, and they were reared on liver: a 30 months' trout, by artificial feeding, at Huningen, attained to 3 lb. weight. Many substances are recommended for young trout, as the heart, liver, and lungs of animals killed for the market, English dog biscuits, dried ants' eggs, ground liver, and brains, horse-flesh, clams (*Pecten*), worms, and maggots, &c. Meat may be boiled and thus employed—three or four parts fresh meat, one part of common flour, the latter being stirred in. If the fish are properly fed, but little of the food goes to the bottom; should it putrefy there, mortality will most probably be occasioned. Diseased meat is poison to fish. Placing minnows in a trout pond has its advocates; while others consider that, as these fish eat the same description of food as young trout, it is unadvisable to locate them together.

As rivers become more polluted, due to the industries which are being carried on along their banks, it necessarily must come to pass that the fish contained therein will be injured, and perhaps the more delicate forms destroyed, unless pollutions are no longer poured into its course, and other means of destruction cease. Failing remedial measures, it becomes a consideration whether it would not pay,' in a commercial point of view, to raise fish, more especially salmonidæ, in artificial streams and well-constructed ponds for this purpose.

In some parts of Germany brook trout are purchased when from only 5 or 6 inches in length, and often brought great distances and fattened. At the ponds they are sorted in accordance with years, and fed on the worthless cyprinoid fishes, which are conveyed in large numbers for this purpose from the Neckar, the Rhine, and the Maine; sometimes the fish, as food, being given alive, at other times dead, the last being found the most fattening. These latter are kept in ponds by themselves, and daily removed and killed for the salmonoids, who receive them dead, but quite fresh. Great care is taken that no remnants are left in the trout ponds, every portion being carefully removed daily.

Fish dealers at Frankfort-on-the-Maine, not having sufficient spring-water for feeding trout ponds, have large floating boxes in the river which are used for this purpose.

In autumn, when the water of the Maine is sufficiently cool, medium-sized fish are caught in the brooks, placed in these boxes, and well fed with live fish; and by the beginning of the next summer, when the river water becomes too warm for remaining, their weight has become doubled or trebled. In the trout ponds of Mayence, Würzburg, Heidelberg and elsewhere, the quantity of spring-water which supplies the feeding ponds is comparatively small. They are, however, kept clean, and especial care is taken that saturated leaves do not accumulate at the bottom. In the large establishment of Klein Brothers, in Alsace, irrespective of the natural food supplied by the Ill to the fish, horseflesh was exclusively used to supplement it. The horses before being slaughtered were carefully examined by veterinary surgeons, and the fish were fed in accordance with their size, the larger ones having it chopped up into small pieces, while it was ground fine for the younger ones. In using this description of meat very great care has to be taken, or it may, if unwholesome, produce a widespread and fatal epidemic among the fish—in fact, in this way Herr Haack lost all his salmonoids, large and small, in one day.

STOCKING WITH FISH FROM A DISTANCE.

It is a subject well worthy of attention when about to procure fish from a distance, as to the race of trout, salmon, or other species which is to be introduced. For fishes, like other animals, are capable of having the stock improved, and in certain waters raised to a better standard ; thus trout eggs sent to Tasmania from Hampshire and Buckinghamshire developed into *Salmo ferox*. But although new stock may tend to improve local breeds of trout, experiments go to show that, where small but not malformed races exist, riparian proprietors had far better investigate the condition of the fish food-supply, the nature of the water in their streams, the geological formation of the soil, and other local surroundings, than solely rely upon the introduction of larger races. For if the character of the water and paucity of food[1] is the cause, sooner or later the new stock will deteriorate, and become indistinguishable from the original local breed in colour, form, or size. Should, however, food be plentiful and the water satisfactory, there can be no question but that some races grow faster and are superior to others : among these superior forms certainly the Lochleven trout must be classed. Not only are some races superior to others, but some fish under suitable conditions attain to a much larger size than their fellows, due, apparently, to their taking on cannibalistic propensities. This will be seen if a number of fry of a stunted race are transferred to localities where food is abundant and the space large, when some only among those which survive will grow to a large size. As we find the older and finer trout produce larger eggs than their younger relatives, while a few recently observed facts go to show that the progeny from these larger eggs grow more rapidly than those from the smaller ones, it appears as if we were commencing to dimly see how breeds could be permanently improved by keeping the breeders of different ages distinct in suitable ponds, so that the ova could be obtained from well-matured parents. This is done at Howietoun; and on this, I believe, greatly depends the marked success of that establishment. On the other hand, it seems to point out that by overfishing, and obtaining the young from the eggs of the smaller parents, breeds may deteriorate, as is so commonly seen in some localities.

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[1] The young of salmon eat food in large quantities which might be utilised for the subsistence of non-migrating trout or grayling.

During the present year land-locked salmon from Maine, in the United States, have been hatched in this country and shown in the Exhibition. It appears to be merely a variety of the common salmon, which in some places has taken on a lake life, and now does not descend to the sea, but lives and breeds in fresh water. Some examples of a land-locked salmon from Lake Wenern, in Sweden, weighing as much as 15lbs., were likewise exposed for sale in the fish-market. It seems well worthy of consideration whether this variety might not be an acquisition to upper riparian proprietors, for, although smaller than its migratory relative, it is said to afford equally good sport to the angler and food for the table. It is well worthy a trial in the upper waters of the Thames. The Canadian Schoodic salmon resorts from the lakes to the streams, mainly for reproduction, but to a very considerable extent for the purpose of feeding. There are two migrations yearly from the lakes to the streams, the first, a partial one in spring, for feeding; the second, in the autumn, for reproduction.

Certain local circumstances may render it desirable to introduce from distant places new breeds of fish; thus, although the presence of salmon was wished for in the Danube, we are informed, in the expressive language of Herr von Behr, that "the Lower Danube is, during summer, as hot as hell," while the Californian streams, where they flow into the sea, are said to be not much cooler. As the Rhine salmon is not suited to the Danube, it was naturally attempted to introduce its relative, *Salmo quinnat.*

The question of hybridisation is worthy of attention, as it has been proved that, besides the various forms of fresh-water trout and the charr raised in vivaria, all are exceeded by bastard fish between the trout and charr, which, observes Director Haack, outgrow the pure breed very considerably even when raised under identical conditions; and, besides rapid growth, their delicate flavour combines the excellence of the charr with the peculiar flavour of the trout. Consequently, among salmonoids, he considers it to be the most suitable form for pond cultivation; while if hybrids are raised between the salmon and the trout, it is still doubtful to what extent sterility will occur among the progeny, and whether they would or would not take on anadromous instincts.

The smelt (*Osmerus eperlanus*) has been successfully hatched in fresh water at Howietoun during the present year, and the living young shown in this Exhibition. They may be extremely useful food for trout and charr. In the United States they have a useful invention for the hatching of smelt eggs.

In 1880 the first attempt in Scotland was instituted. The eggs were spawned into a pudding-dish and milted by the dry process; they were then placed at the bottom of a slow current of water in the open air; but all died of fungus about the fourth day. In 1881 another series of experiments were commenced. The eggs were placed in a wooden box, the bottom of which was composed of glass grilles. This box was placed inside one of the hatching-troughs, and a current of water was forced up through the glass-grilled bottom of the box which contained the eggs, keeping up constant motion. They lived for three weeks.

This year about 160 smelts, in breeding condition, were captured in the tidal waters of the Forth, and sent in fresh water to Howietoun by Mr. Napier, Inspector of Salmon Fisheries. As a rule, the females appeared to be larger than the males, but this was not invariably the case. The colour of the eggs varied from yellow to clear white, and the fish were spawned when the temperature stood at about 49 degrees, while at 45 degrees the milt became silky. The eggs were received on to a piece of window-glass, and milt was added; subsequently a little water, and by gently shaking the glass the eggs were dispersed over its surface. In about five minutes they adhered to the glass, which was then placed on end in one of the hatching-troughs. The adhesion of the eggs is due to a fine filament which is attached to the outer surface of the egg, and expands at its distal extremity into a sucker, by means of which it becomes adherent to any contiguous object. When the eggs were placed in too great proximity to one another, they, on swelling, became pressed, and their surface looked as if they were honey-combed. If two layers of eggs were present, the upper became covered with fungus—perhaps due to the length of the filament being unable to reach a spot where it could adhere. If torn off from its adhesion, death appears to result. By leaving a little clear space round the eggs pressure was prevented, and they hatched in a satisfactory proportion; this hatching occurring about the forty-second day, except in some troughs which had been kept warmer, when it occurred eight days sooner.[1]

In Maryland, in America, an attempt was made to artificially propagate the ova of this genus in 1877, but it proved unsuccessful. Since then, in 1879 and 1880, a few have been hatched on the Hackensach river (New Jersey), and preparations were made in 1882 for extensively hatching these fish by the United States Fish Commission.

The following box for smelt-hatching exists in the United States section:

RICARDO'S SMELT-HATCHING BOX (plate I, fig. 7).—A rectangular box, with a hinge-cover and perforated ends, covered with wire-cloth. The inside of the box is filled with twigs, to which the adhesive eggs of the smelt are attached.

This box is placed in the river where the current is strong, the water entering and escaping through the circular opening at the end.

Among the salmonidæ found in our lakes, in Wales, the North of England, Scotland, and Ireland, are the white-fish, or *Coregoni*. Some species are likewise present in Canada and the United States, where the ova of the *C. albus* have been artificially propagated with great success.

The eggs of some fishes, as the American white-fish (*Coregonus albus*), when dead become of a lighter specific gravity than are the live ones. The separation of the dead of these comparatively small eggs from the living was a source of great difficulty, but which has now been overcome by means of self-pickers. A regulated current of water descends upon the ova, sufficient to allow the dead eggs to pass off with the overflow.

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[1] These fish subsequently died.

WILMOT'S IMPROVED GLASS INCUBATOR (plate III, fig. 18)—for the self-picking, cleansing, and hatching of eggs, of the Coregoni and Percidæ species—is a cylindrical jar made of glass (or any kind of metal) of any size or shape; a rubber-pipe, attached to a tap, regulates the supply, conveys the water into a glass tube, which rests on the bottom of the jar. The water striking the bottom glances equally round and upwards, passing through the eggs, gives them a gentle motion, and carries off all light and impure eggs and sedimentary matter through the lip or overflow, and leaves the sound eggs, from their greater specific gravity, at the bottom of the incubator. The apparatus is very perfect, and largely used in Canada and the United States.

In the United States Section exist several plans having much the same purpose in view.

CLARK'S HATCHING-JAR (OLD STYLE).—A cylindrical jar of glass, with a metal rim notched at one side, and provided with a movable wire screen, which is open while the embryo are developing, to allow the escape of dead eggs, but closed when the hatching begins, to prevent the escape of the fish. The water is introduced through an opening at the bottom, passing upward through the eggs and out at the top. Formerly extensively used for hatching eggs of the white-fish. Height, 16 inches; diameter, 6 inches.

CLARK'S HATCHING-JAR (INTERMEDIATE FORM).—A cylindrical jar of glass, with a metal rim, having a spout on one side through which the surplus water escapes. The water is introduced at the bottom, through a tin tube with a funnel-shaped opening, and passes upward through the eggs on its way to the outflow-spout. Height, 16 inches; diameter, 6 inches.

Extensively employed for hatching eggs of the white-fish at the Fish Commission hatching-station at Northville, Mich.

CLARK'S HATCHING-JAR (NEW STYLE).—A cylindrical jar of glass, with a metal rim, having a spout at one side from which the surplus water escapes. The bottom of the jar is provided with a metal cone corresponding with the funnel-shaped end of the supply tube, which is prevented from coming in contact with it by means of slight projections on its inner surface. Height, 18 inches; diameter, 6 inches.

This jar is now coming into favour for hatching eggs of the white-fish, and is extensively used at the Northville hatchery.

CHASE'S HATCHING-JAR (plate II, fig. 14).—A cylindrical jar of glass, with a metal rim notched at one side and provided with a wire screen for retaining the fish. The water is introduced through a glass tube at the bottom and passes upward through the eggs. Height, 16 inches; diameter, 6 inches.

This jar is extensively used for hatching eggs of the white-fish. When the embryos are developing, the outflow-gate remains open, and through it any dead eggs which are carried upward by the current escape, thus preventing the injurious effects which arise from fungus and dead eggs.

MCDONALD'S Y-SHAPED HATCHING-BOX.—A wooden box, with glass ends and sloping sides, for eggs. Length, 12 inches; width, 24 inches; depth, 15 inches.

The sides of the box slope toward the bottom centre until they come within an inch of each other. Below this opening is a space three or four inches deep for the introduction of water. This opening is nearly closed by means of an adjustable square wooden bar, one of the angles of which enters the centre of the opening, the sides of the bar thus being parallel with those of the box. By this means the current is divided so that the water is deflected along either side of the box toward the surface, carrying the eggs with it and causing them to pass in toward the centre and fall again to the bottom, where they are again caught by the current and carried through the same circuit. The outlet is protected by a triangular trough running across the top centre from side to side. This is placed a little below the top of the box, so that the water shall flow over its side and out through the openings. The current introduced is sufficiently strong to carry away the dead eggs into this trough, thus allowing them to escape; but is not strong enough to carry away the good eggs, which, being heavier than the dead ones, drop before reaching the trough. Great care must be taken to see that the flow of water is properly adjusted; otherwise many of the dead eggs may be retained, or the good ones may be lost.

SECTION OF V-SHAPED HATCHING-TROUGH.— A simple trough, with false sides sloping downward from the top toward the centre, leaving the space of $\frac{1}{8}$ of an inch, covered with wire cloth, between their lower edges. The upper part of the trough is surrounded by perforated tin, through which the water passes into a sluice-way and thence to the escape-pipes, which occur at short intervals.

The water enters the apartment between the vertical and sloping sides with the hydrant pressure, and is forced up through the opening and out through the strainer at the top. The eggs, being heavy, tend to sink to the bottom, where they are caught by the current and carried upward and outward toward the sides; as the current weakens, they gradually drop back toward the centre, where they are again caught and carried through the same circuit.

FISH-PONDS.

It is not surprising that pond-fish in this country are generally deemed hardly fit for the table, because, consequent upon the want of care bestowed on our ponds, the fish obtained from them have, as a rule, a muddy or an earthy flavour. Were, however, attention paid to this subject, many fish-ponds now left to be choked by mud, and rendered foul by the accumulation of decomposing leaves and decaying weeds, might be rendered clean, sweet, and capable of supplying a considerable amount of good and eatable table fish. Fish-ponds, as has been pointed out by almost every fish-culturist from ancient to present times, must not be left unattended to; they may be allowed to stand full two or three years, but not longer, unless the proprietor delights in the contemplation of starved fish: the oftener they are dried, the better the feed for the fish will be. The best treatment for these ponds is rotating crops of vegetables and crops of fish, for which purpose at least three ponds are required, although more are undoubtedly advantageous.

The aspect of the ponds, the nature of the soil in which they are constructed, the character and amount of the water which supplies them, are all factors to be taken into account and upon which success or failure frequently depends. Hard clays and gravels are generally unfavourable, while a marly soil is mostly to be preferred. Near the middle of the pond a deep spot should be constructed into which the fish can retreat if necessary. They should not be too deep, as shallows are necessary for the fry, which are rarely seen in deep water, which latter is colder than shallows and consequently is frequented by fewer insects, irrespective of which, cold does not favour growth in these fish. Most forms of trees in their immediate vicinity are detrimental, because leaves falling into the water, occasion the formation of a black mud and the escape of fœtid gases, which appears to be especially deleterious in winter, when ice covers the surface. Rank vegetation along the banks is often injurious, although some weeds in the water are necessary to afford shelter for ova and fish, as well as clear the water. In some ponds facilities may advantageously be afforded to cattle to come and drink, as well as stand in the water, thus augmenting the food of the fish: but the vicinity of rookeries has been deemed to be deleterious. Care should be taken that surface-water from the neighbouring land cannot obtain access, and if necessary a channel should be cut to keep it away.

There are many modes in which fish-ponds may be constructed, but an invariable rule should, if possible, be made, that means should be present by which, when desired, they may be readily run dry, and the same depth should be maintained summer and winter. Along the centre of the pond, from where the water enters to its outlet, two or three deep channels should be cut, and about the middle of the pond is a deep spot termed the kettle, two feet deeper than the pond; while near the outlet is another spot one foot deeper than the rest of the pond. The inflow of water should never be direct from a brook, but conducted in from one side; the sluice situated there should be sufficiently strong to render overflowing impossible, while a grating should exist to keep out strange fish. The outlet may be made of masonry or pipes, and also be guarded by a grating to retain the fish. Spawning ponds of a small size have been found in carp cultivation to answer better than larger ones. The stream of water should be able to be cut off when desired from any of the ponds; while, if a succession of ponds exist, fish of various sizes can be kept by themselves and suitably fed and fattened for culinary purposes. If, says Roger North (1713), there be only two ponds, the first should be dried in October, by drawing the sluice, and as the water gradually subsides, the fish should be taken by degrees; but he recommends that the mud should not be removed, for fear of injuring the banks, but would rather plant a crop of osiers in the mud, or oats will grow well there. When dry, he proposed that it should be kept so all the summer, and a profit made out of the soil by ploughing or feeding. Ponds may be purified (if not very foul), and the weeds killed, by being allowed to remain dry for a few months. The following Michaelmas, or a little sooner, they should be filled again, and, when nearly full, stocked.

An interesting paper upon pond cultivation in Prussia, by Herr Eben Banditten, exists in the *Deutsche Fischerei-Zeitung*, v., No. 6, February 7th, 1882. He had a meadow ten acres in extent in a very favourable and sheltered position, which was alternately employed as a pond for rearing fish and for agricultural purposes. In August 1881, when the second crop of grass was just ready for cutting, a flood covered it to the depth of five feet. In previous years he had employed it as a spawning pond, now he decided to use it for raising and fattening carp. Knowing the quantity of food it contained, he stocked it in the spring with about five hundred carp, weighing on an average 1 lb. to 1½ lbs. each, four hundred ides (*Cyprinus orfus*) of different sizes, a few eels and ducks in the proportion of one to each carp. He succeeded very well, 300 ducks, 100 geese, and 2 swans, making this pond their residence for the summer. He expected, and found his expectations fully realised, that these aquatic birds would furnish a good deal of other food for the carp. Frogs at first abounded, but the ducks cleared them off. About the beginning of October 1881, he had about 50,000 very fine young carp, 100 of them weighing about 2½ lbs.,; of ides he had only about 100. The old carp had increased in size from 100 to 150 per cent., the ides not quite so much. Frog spawn was found to be good food for ducks, and thus increased the fishes' food.

The number and sorts of fish suitable for stocking ponds depends upon many circumstances, especially as to the amount of food which is present, whether the water is from a stream or springs, and many other conditions. Boccius recommended the following proportions of fish as suitable for stocking an acre of water: 200 brood carp, 20 brood tench, 20 brood pike. North cautions the fish-culturist against over-stocking, observing that when this is done the fish deteriorate. Also that after the first year their numbers should be diminished, because the food will be less. It is well when drying a pond to examine whether the contained fish are well-fed or lean, and accordingly judge whether the water has been under-stocked or over-stocked.

One of the first accounts of the mode of hatching coarse fish, as perch, pike, roach, bream, ide, and aspius, is by C. F. Lund, in the transactions of the Academy of Science of Sweden in 1761; it is entitled 'Fiske plantering.' The principle is a box placed in shallow water near the bank of a river, where the water does not flow over: its inside is charred by fire and then lined with bushes, while its sides are perforated in order to permit free access of water (see plate I, fig. 5). Here the parent fish are confined, and when the eggs have been deposited the old fish are usually eaten by the peasants, who are not particular as to the taste or quality of their food. This process of spawning and hatching coarse fish which breed in summer has been improved upon by Mr. Oldham Chambers, who has made the sides movable, so that they, with the bushes and adherent ova, can be transported in carrying-boxes to desired localities.

RIVER AND POND FISHES.

The fish-culturist who has decided upon raising food fishes in a pond has first to investigate what indigenous or foreign forms are best suited for his purpose? In the following brief summary the salmonidæ and anadromous fish are excluded, as they form a separate subject for inquiry.

The perch (*Perca fluviatilis*) is a well-known gregarious fresh-water form which inhabits lakes, ponds, canals, and rivers, more especially frequenting deep holes or where there is a gentle current, preferring the sides to the more rapid parts of streams. Occasionally it will descend to salt water, and when found in such localities, or where it is brackish, it is highly esteemed; on the contrary, in muddy ponds it loses its flavour; it is generally held in good repute as a table fish. Being very fond of fish fry it is not an advisable form in salmon or trout waters. At its third year, and when about 6 inches in length, it commences spawning, depositing from 20 to 28,000 ova. It does not often exceed 3 lbs. in weight.

In the United States Section is shown an apparatus, MACDONALD EGG REEL (plate IV, fig. 22) for dealing with adhesive eggs, the mucus on which hardens under water. The eggs are taken upon cotton yarn, which is drawn up through a funnel into which the milt and eggs had been squeezed from the spawning fish. The thread covered with adhering eggs is rolled upon a wooden reel and sent in damp cloths to its destination. On arrival the cotton cord is cut into lengths of 10 or 12 inches, and suspended in glass hatching-jars.

The burbot, or eel-pont (*Lota vulgaris*), prefers clear and still rivers and lakes, at the bottom or sides of which it lurks in holes or crevices among the stones, or even skulks in rat-holes or cavities under banks. In stews it fattens well, as it will eat almost any animal substance. It has long been esteemed a great luxury; its flesh is white and delicate, but its liver is its most delicious morsel. It is found in the county of Durham; also in sluggish Yorkshire rivers, in Norfolk, in the Trent and its affluents in Nottinghamshire and Staffordshire; in the great east fen of Lincolnshire, and also in Cambridgeshire. It breeds from December to March, depositing at least 128,000 eggs. It appears to be decreasing. It is usually found up to 2 lbs. or 3 lbs. weight in this country, but occasionally larger.

The pike or jack (*Esox lucius*), is a strong, active, and voracious fish, consuming its smaller neighbours, preferring still and placid waters where weeds abound, and among which it will lurk. When emboldened by hunger nothing comes amiss, and it has been suggested that in lakes where trout are numerous and of small size it may be a good plan to introduce a few male pike to keep down the numbers, and thus proportion them more to the amount of food. The same plan has likewise been employed among coarse fish. Of its value as food opinions differ, but the river are superior to the pond ones. It has been observed that boiled, it is insipid; stewed with spices and a bottle of good old crusted port, it becomes passable; stuffed and baked, it is perhaps a trifle better; filleted, it is almost nice. In some trout rivers it appears to have entirely destroyed the native races. In carp ponds it is said to prevent the Cyprinidæ from becoming lazy by chasing them about. Breeding in March and April, it deposits from 700,000 at 28 lbs. to 292,320 eggs.

Carp (*Cyprinus carpio*).—Hardy and tenacious of life, wary in a state of nature, but readily tamed, it is most frequently found in ponds, canals, sluggish pieces of water or slow-flowing rivers. Its flavour is frequently muddy, to obviate which it is found advisable to retain it for some weeks in a stew, through which a supply of water flows. It can be conveyed long distances in well-boats, through which water is allowed to pass; and experiments made in America show that it can be transported in railway vans when only sufficient water is sent that will cover its back, and it has thus been carried for nearly four days without ill-effects. It is supposed to commence breeding at three years old, in May or June, according to the character of the season; the eggs develop quickly, the eyes becoming visible as early as the fifth or sixth day, and on the twelfth or sixteenth the young hatches. Carp of about 4 or 5 lbs. has from 400,000 to 500,000 eggs. This fish is largely cultivated for food in some countries, while in Paris, in spite of an abundant supply of marine and fresh water forms, it, with the exception of salmon and trout, is considered the most desirable form. In this country the best are from rivers, next such as come from large lakes, and the most inferior from muddy ponds. It mostly subsists on vegetable food, but also on worms and larvæ of water insects which it turns up from the mud with its head; also refuse from slaughter-houses and reservoirs. It may be considered as in season from October until April. To improve their flavour Mr. Tull castrated them, as he asserted, with excellent results. It is found up to twenty pounds' weight in this country. In employing carp as food fishes great care is very desirable in selecting the race which is going to be imported; in Germany and elsewhere, there are three varieties which are cultivated—the common carp, the mirror carp, and the leather carp. Of these three races the mirror carp is considered the superior, being the most hardy form, and bearing up best against injuries. Some fish-culturists make a speciality of raising forms possessing very few scales; sometimes these are restricted to a single row along the lateral line, or a strip along the back. Crucian carp (*Carassius vulgaris*) will cross with this form, the progeny being almost worthless for the table. The crucian and gold carp should not be permitted in the same ponds as the common carp.

Carp require a hatching-pond, which should not exceed one to one and a half feet in depth or less in parts, and having weeds in it on which the eggs are deposited. Secondly, a breeding-pond about the same depth; and thirdly, a culture or regular carp pond. Should sufficient food not be naturally present, the fish must be fed, but never in the same spot, as they become languid and lazy; the flesh of a carp that does not take exercise is rarely firm. They should have a little food at a time—early in the morning and late at night, or in very warm weather only in the evening. Pond carp, observes Hessel, are accustomed to other food than river carp. The former confine themselves to worms, larvæ and plants, while those living in streams find all sorts of animal and vegetable refuse: these latter can also stand a greater amount of food, as the current materially inclines them to take more exercise, thus increasing their appetite; while when feeding on unwholesome or spoilt food, or food left to spoil due to not being eaten, will produce disease. An old rule was to feed carp in spawning-ponds both before and during spawning, in order to prevent their hunting for food and consuming their own eggs. After spawning, the adults should be removed. Too many young fish should not be left in one pond, but in cold countries they may remain two summers.

In the United States Section are two plans for transporting carp, the first one used being termed a—

CARP TRANSPORTATION CAN.—This is a cylindrical tin can, encased in wood, with the top slightly contracted to prevent splashing.

Diameter, 10 inches; height, 13½ inches; capacity, 6 gallons.

This can holds ten three-inch carp. It was formerly extensively used in the transportation of this species, but it is now seldom employed, as small pails are found more convenient, less expensive, and equally satisfactory.

CARP TRANSPORTATION CRATE.—A wooden crate, provided with sixteen two-quart tin pails, arranged in two tiers, separated by a wooden partition.

Length, 32 inches; width, 18 inches; depth, 14 inches.

This crate has now almost wholly superseded the more cumbersome and expensive cans. In shipping cans intended for different persons in the same section and placed together in the same crate, each is provided with a tag bearing the name of the consignee. On its arrival at the proper railroad centre, the crate is opened by the employés of the express company, and the cans reshipped to the parties for whom they are intended.

The gudgeon (*Gobio fluviatilis*) is a small gregarious river fish, selecting places where the current is not strong and the bottom sandy or gravelly, seeking the shallows during the warm months, but returning to deeper water in the winter. They will succeed in some ponds, whether muddy or clear, and have been even observed to breed there, although the bottom was clayey. It breeds from April until June, depositing its eggs in shallows, where they hatch in about a month. Those from rivers are a very delicate fish, and are often termed the "river smelt." They form good food for other fishes.

The roach (*Leuciscus rutilus*) is a gregarious fresh-water fish, preferring clear and still waters, found feeding at night on the shallows, but retiring to the deeper parts during the daytime. It is in little estimation for the table, but useful as food for other fishes. It breeds in May and June.

The chub (*Leuciscus cephalus*) is found in rivers, where it frequents localities overhung by banks and trees, the eddies of weirs or bridges, about mills and in other suitable places. It is a coarse, bony fish, spawning in April and May.

The dace (*Leuciscus vulgaris*) is another gregarious river fish, not much esteemed for the table, but which forms useful food to its better class of neighbours, while its bright silvery sides render it very suitable as bait for pike. It spawns in June, and one of 28 ounces contained 480,480 eggs.

The rudd (*Leuciscus erythrophthalmus*) is a gregarious fish found in many rivers, canals, lakes and ponds. It is not much esteemed for the table, but some anglers prefer it to dace as a bait, when trolling for pike, as it is more tenacious of life. It breeds in April and May.

The minnow (*Leuciscus phoxinus*). During the summer this pretty little fish is found in large shoals near the surface, but more or less conceals itself during the cold months, while it prefers clear and rapid water. It spawns in June, and the young are hatched about the sixth day.

The tench (*Tinca vulgaris*) inhabits lakes and ponds, becoming more or less dormant during the winter months. It is very tenacious of life, and some esteem it as good food. It breeds in June, and upwards of 250,000 ova have been taken from one fish. A golden variety has been introduced in this country and extensively propagated; but as food it is inferior, while it is more readily perceived by its enemies.

The bream, or carp bream (*Abramis brama*) is a gregarious fish found in rivers, canals, lakes, and ponds, thriving best in large pieces of water, in quiet rivers, and sometimes in enormous shoals, as in the Norfolk broads or Irish lakes. It spawns in May. Although by some it is said to be good for eating, others reject it as bony, muddy, insipid, and only fit for pike and other predaceous fishes.

The white bream, silver bream, or breamflat (*Abramis blicca*), has much the same habits as the last, than which it is, if anything, considered as still more inferior, but good as food for pike.

The loach (*Nemacheilus barbatula*).—This little fish is found in rivers and brooks, when, if disturbed, it darts away or stirs up the mud for concealment. It generally hides itself under stones or other objects, and is mostly nocturnal in its habits. It breeds in March and April. It is a very good bait for trout, perch, pike, and eels.

The eel (*Anguilla vulgaris*).—The common eel, almost cosmopolitan in its distribution and a catadromous form, descends to the sea to deposit its numerous ova, while it inhabits all pieces of fresh water to which it can obtain access, thriving better in rivers having muddy bottoms than in those which are gravelly; migrating twice a year—in the autumn to the sea for breeding purposes; in the commencement of summer from the sea, the latter being almost entirely confined to small fry, termed elvers in some localities. In the winter eels conceal themselves in the mud. They are very destructive to the spawn of other fishes, consequently are not always advisable in fish-ponds. Holland supplies, at the least, half the amount of eels consumed in this country, deriving in exchange a considerable income; while we, who find our local supply insufficient, do not take steps to prohibit the sale of elvers, or young eels, which are captured in quantities and pressed into what are called elver cakes, 1408 fish going to 1lb. weight. These elvers ascend some of our rivers (as the Severn) in millions, and would prove very remunerative if reared in suitable localities, besides obviating the present necessity of eels being imported from abroad.

FOREIGN FISH FOR ACCLIMATISATION.

Some fish-culturists advocate the introduction into this country of foreign forms of fish, either from the continent of Europe or more distant climes. Such a proceeding may be beneficial or may be entirely the reverse. The first consideration should be, if the stranger is a large consumer of vegetables or flesh, and whether sufficient exists for his consumption where it is proposed to acclimatise him. Anadromous forms, as the salmon or shad for instance, as a general rule merely enter our rivers just prior to spawning time, a period when they require but little food, and consequently, until spawning is over, do not need any very large amount of sustenance. Carnivorous forms, as pike, may be useful to diminish too large a number of coarse fish in a river where they are in excess of its capabilities for supplying them with food; but when the wished-for diminution has occurred, they still continue their depredations, and may deplete the fisheries to too great an extent. Attempts were made, which were fortunately unsuccessful, to introduce the *Silurus glanis* into our rivers, a fish with an insatiable appetite, and when large, of but little value, except for the oil which can be obtained from it, and which Professor Rudolph Hessel described as having habits similar to the carp, lying on mudbanks, or feeding-places of this fish, becoming its most dangerous enemy and insatiable destroyer.

ARTIFICIAL HATCHING OF MARINE FISHES.

The principle acted upon in some freshwater fisheries of supplying undue depletion by artificial hatching of fish has likewise been attempted in the United States with respect to sea fisheries. It is carried out there by Government Commissioners, who, unwilling to regulate the modes of capture, but observing the evident impoverishment of the fisheries, plainly perceive the inutility of expecting the fishermen to stock public waters at their own expense, and where everyone might indiscriminately capture the produce. Here we go on a much simpler plan ; ignore the complaints of the fishermen that the inshore fisheries are being depleted, assert they are ignorant of what they are complaining about, be incredulous of the statements of success from other countries, profess to believe that the excessive rise in the cost of fresh fish is due to some trick of the fish-selling trade, and calmly await the time when our flat-fish fisheries have followed those of our oysters, leaving untouched the question of why it is that now at least two or three times the amount of netting, number of men, and of tonnage of boats are necessary to obtain a similar amount of fish to what was taken at the commencement of this century.

The first species which the United States Fish Commissioners attempted to propagate on a large scale was an anadromous shad, *Alosa sapidissima* (a genus of which we possess species in this country), which up to 1877 had been chiefly artificially carried on in floating boxes, connected in a gang by cords, the foremost being held in its place by an anchor. It was found that during strong currents there was sufficient movement for the eggs; but when the tide was slack they rested in masses at the bottom of the boxes, and in consequence suffered greatly, being very liable to fungus, especially when the temperature was high, unless shaken up by the hand; while during storms or floods they were not infrequently upset or carried away. In 1877 Mr. Ferguson invented his PLUNGING-BUCKET (plate III, figs. 15, 16), which apparatus had a great superiority over floating boxes, especially in hatching eggs in waters where all currents were absent; also because a cooler stratum of water could be readily reached when the surface was too hot for the proper development of the eggs, a condition always present when the temperature rose above 80°. By covering the tops of the buckets with caps of wire gauze they might be sunk to the required depth where a cool stratum existed, and that without any escape of the ova. The apparatus is thus described: "It was placed upon a large scow, 50 feet long and 19 feet wide, and consists of a shafting along the centre of the scow, upon which at intervals are placed irregularly formed cams, which have a long and a short side. This is accomplished by making the outline of the cams two intersecting cycloid curves, which produces upon the lever following its circumference a quick fall and slow rise at the extreme end. A steam-engine is the motive power revolving the shafting and cams. To the ends of the levers are suspended cylinders of sheet iron, from 1½ to 2 feet in diameter, having a wire-cloth bottom, and within these cylinders the eggs are placed. The rise and fall in the water does not exceed 5 inches. A slow revolution of the shafting produces all the agitation in the water essential to the welfare of the eggs, a more rapid motion having a tendency to draw the eggs hard against the wire-cloth. The slow rise and quick fall of the cylinders also saves the eggs from this injury, as the effect is to throw the eggs high up as the bucket goes down, while, as it rises slowly up, they fall gently to the wire-cloth bottom." Each bucket will hold 20,000 shad eggs. In many localities where this artificial shad propagation has been carried on the success has been very great. In 1867 two million, and in 1869 four million, were hatched in the Connecticut river; and in 1872 the largest catches were made that have occurred since 1811. In the river Hudson, it was reported that the take of shad was the greatest that had been seen for fifteen years, and the results of its culture were beginning to be seen. In short, in many localities where this artificial propagation has been carried out, the increase of fish has been most remarkable; while new colonies of them have even been established.

WRIGHT'S SUBMERGED WAVE-ACTION HATCHING-BOX. —(Plate III, fig. 19).—A cubical box, with a hinge cover of wire-cloth, the sides being of galvanised iron; the bottom, which is of the same material, being provided with circular openings an inch in diameter, each covered with valves opening upward to admit water from beneath. In the interior of the box, an inch above the valves, is a wire-tray upon which the eggs are allowed to rest, and through which the water can readily pass. The sides of the box are prolonged downward to form an expanding rim, which serves to deflect the current upward through the eggs. The whole is suspended from a float, and held in position by means of a small weight fastened to the bottom.

Length, 10 inches; width, 10 inches; depth, 12 inches.

This box was invented for hatching eggs of the shad. It is claimed to be suitable for open streams where the current is too slight to admit of the use of other apparatus.

MACDONALD'S EGG-TRANSPORTATION CRATE.—A crate containing 18 shallow trays or wooden frames with wire-cloth bottoms, incased in canvas, and secured by frames connected by leather straps.

Length, 16 inches; height, 15 inches; width, 14 inches.

This crate is used for transporting the eggs of the shad for a distance of fifty to one hundred miles. The bottoms of the trays are covered with wet cloths, upon which the eggs are spread. Each tray holds from 10,000 to 15,000 shad eggs. When filled, they are incased in the cloth cover, securely strapped together, and shipped by boat or rail to the hatchery.

This apparatus marks the beginning of the dry transportation of shad-eggs, and has been successfully used in the work of the United States Fish Commission for the past two years.

FISH COMMISSION TRANSPORTATION CAN.—A cylindrical can of block-tin, the top of which is contracted, and provided with a cover to prevent slashing of water while in transit.

Height, 24 inches; diameter, 14 inches; capacity, 12 gallons.

This can is more extensively used than any other kind for the transportation of young shad, and proves very satisfactory. The contraction of the neck, giving only a limited free surface, prevents any violent agitation of the water.

FERGUSON'S TRANSPORTATION CAN.—A cylinder of block-tin, with movable top fitted with a rubber rim, and thumb-screws for rendering it water-tight.

24 inches high and 14 inches in diameter. Capacity, 12 gallons.

This can is provided with nipple attachments, by means of which several can be connected, so that a current of water will flow from one to another, thus giving a circulation during transit. This can carries from 15,000 to 30,000 shad.

The ova of the cod have been artificially propagated, as it was considered possible not merely to increase the supply where it already existed, but also to establish new fisheries in places where the young should be turned out. The best results are said to have been obtained at Gloucester, Mass., where those released were known to live, as many young fry were observed playing round the wharves where young cod had never been previously seen. The eggs having been taken in a pan having a little water in the bottom, and the milt was at once added, after which water was slowly mixed at intervals until the pan was full. But for successful hatching it appears necessary to give a certain change to the water, and partially keep sediment from the eggs. Various contrivances have been invented in order to ensure this result; one known as CHESTER'S SEMI-ROTATING hatcher (plate IV, fig. 24) is thus described :—

his consists of a tin cylinder, 18 inches in diameter, and 24 inches deep; with four rectangular openings, each 2½ inches wide, extending from near the bottom to within 5 inches of the top. These and the bottom of the cylinder are covered with wire-cloth, to prevent the eggs from escaping, or the dirt from entering. On the outside of the cylinder, along one side of either opening, are placed strips or pockets of tin, at an angle with the side, and extending partially over the openings, so that the adjacent pockets face in opposite directions. As the cylinder rotates on its axis, the water is forced in at the two opposite openings and out at the others. Beneath the wire-cloth bottom are four more strips of tin, radiating from the centre, and placed at such an angle that the rotation of the cylinder presses the water against them and up through the bottom. The whole is placed in a trough nearly filled with constantly-changing water, and sunk to such a depth that the water nearly fills it. The cylinder turns on a pivot, the power being supplied from the engine by means of shafting, to a horizontal arm firmly fixed to its axis, and is kept constantly turning back and forth through an arc of 90°, thus keeping the water changing, and giving the eggs a tendency towards the top centre. With this process fairly good results have been obtained. The time required for the development of the eggs varied greatly, being considerably affected by the temperature of the surrounding water. Of those of the cod taken on November 13th the first hatched in thirteen days, while some of those secured on December 17th required fifty-one days.

It was found that spawning fish could be collected off the American coast with little difficulty, and brought to the harbour alive in a common welled smack, and then transferred to the hatchery, where, if necessary, they can remain to ripen, and thus hundreds of millions of eggs can be secured in a single season. The young hatch well, and appear hardy; and, as observed from the ovaries of 25 good-sized cod-fishes, if all the eggs were hatched, would furnish more fish in number than are captured in one year by the combined fleets of cod fishermen from all the different fishing ports in the United States during the most prosperous season.

WAVE HATCHING-BOX. (Plate II, fig. 13.)—A rectangular box, with a wire-cloth bottom and openings covered with the same material on the sides. Just below these, on the outside of the box, are wooden strips which serve as floats for holding the box in the proper position in the water.

Length, 32 inches; width, 17 inches; depth, 16 inches; float, 3 inches wide.

This box is employed in open streams for utilising currents caused by the action of the waves. The box, when placed in the water, sinks to such a depth that the floats which extend around its exterior rests upon its surface. The upper portions of these floats make a slight angle with the surface, so that each wave as it comes in contact with the float runs up a slight incline, and after reaching the highest point, passes down into the box, thus giving a constant circulation, and the best possible motion to floating eggs. The original form of box was supported by hollow air-tight tin cylinders, as shown in plate II, fig. 10.

BRACKETT'S HATCHING-BOX. (Plate I, fig. 4.)—A rectangular box of wood, the front end of which slopes inward at an angle of 45° for the purpose of deflecting the current. The bottom is covered with wire-cloth, and the water is forced through it by means of a tide-strip attached to its further edge.

Length, 22 inches; width, 20 inches; depth, 12 inches.

BRYAM'S FISH-HATCHING BOX (plate II, figs. 11 & 12) may be employed in shallows, or in stormy and agitated waters. It has its riding or breasting end inclined and supported upon the surface of the water by floats, at right angles to the length of the box.

PARKER'S ROTATING HATCHER.—A windlass connected with a system of cog-wheels, which communicate motion to the hatching-cylinder by means of an endless chain. The cylinder is made of perforated tin and wire-cloth, to admit of a free circulation of water. On the inside, suspended from the axis, is a small basket or trough which contains the eggs. Diameter of hatching-cylinder, 10 inches; width, 4 inches.

The motion is communicated to the windlass, and thence through the clock-work to the hatching-cylinder, by means of a weight which is suspended from the end of the windlass rope. The weight is raised by means of a crank attached to the windlass, and the distance through which it falls is considerably shortened by the use of compound pulleys.

AUTOMATIC TRANSPORTATION CAN.—A cylindrical can of copper, with contracting neck to prevent slushing, and a movable cover, the centre of which contains a brass plate with tubular openings, through which the water enters and escapes. Height, 18 inches; diameter, 14 inches.

To the inner end of the outflow-pipe is attached a wire frame, covered with cloth, which serves as a strainer to prevent the escape of the fish. The outer end of the other tube communicates with a reservoir of water by means of rubber tubing. When several cans are fed by the same reservoir they are placed side by side, and so connected that the water passes readily from one to the other.

The eggs of pollack (*Gadus pollachius*) have been likewise artificially treated in the United States; although they float similarly to those of the cod, they are smaller, and appear to develop more rapidly, hatching at most in five or six days with water of the ordinary temperature. A 23½ lb. fish had over 4,000,000 eggs; and a 13 lb., 2,500,000.

Haddock's eggs were hatched in 8 or 9 days in a floating box.

Herring's eggs adhere to any substance they are first brought into contact with. Consequently they should at once be placed in the situation it is proposed they shall remain until hatched. Up to now the young placed in artificial hatcheries have been found to die after the absorption of the yolk sac.

In the Exhibition is an apparatus for hatching DEEP SEA FLOATING EGGS (plate IV, figs. 23 & 29), invented by Mr. Oldham Chambers upon the same principle as the "Thorough" Vase for rearing trout fry, with this exception, that the supply pipes are perpendicular and perforated not only at an angle of 45 degrees, but with an upward tendency, thus assisting the ova to float during the period of incubation.

This apparatus is intended for hatching the eggs of the cod.

Mr. Oldham Chambers also exhibits an apparatus for hatching DEEP SEA ADHESIVE EGGS (plate IV, fig. 27), such as the herring, consisting of an oblong box about 5 feet in length, 2 feet in width, and 1 foot in depth, in which are placed screens covered with muslin, upon which the ova are deposited, and the sea-water passes through the box.

MARINE VIVARIA.

Among subjects well worthy the attention of fish-culturists are the formation of vivaria for the reception of marine fishes, so that a constant supply for the market would be available, even at such periods when gales preclude the sea-fishermen from carrying on their occupation. These vivaria may be either entirely supplied with salt water by tidal influence, or they may be lakes wherein the lower portion consists of salt or brackish water and the upper of fresh, being even fed by a stream. In order to be a pecuniary success the necessary food should be obtain-able in the vicinity at a cheap cost, whether such be shellfish, fish, meat offal, or manufactured substances. Likewise, if an insufficient local demand for fish is present, the means of inexpensive and easy carriage to a suitable market should exist. Several such vivaria have been formed on a small scale around the British Isles, at various times by different individuals.

Parnell drew attention to a salt-water vivarium for fish near North Queensferry, where a number of marine forms were kept in a pond about 200 feet long and five fathoms deep, and into which the tide ebbed and flowed twice daily. All the fish appeared to thrive well, especially the cod, which were found to be firmer in the flesh and thicker across the shoulders than those obtained in the Firth of Forth. Yarrell also alluded to similarly formed vivaria as existent in the Orkneys and in Fife. At Port Logan, in Wigtonshire, an excavation existed in the rock about fifty feet in diameter, while at low tides about eight feet of water remained in the basin and an additional six feet at high tides. Here cod thrive and are always available for the table. In these vivaria it is necessary to regularly feed the fish.

The Romans were accustomed to keep fish for the table in large vivaria, some of which were supplied with salt, others with fresh water; the former, however, were so expensive as to be only within the means of the wealthy. As time went on, these stews appear to have been frequently kept by their owners as a source of profit, and various modifications from time to time were introduced, during the course of which it seems to have been ascertained that many marine forms could be accustomed to a fresh-water state of existence.

This phenomenon of marine fishes changing their condition of life, so that they become either temporary or permanently occupants of fresh water, has for centuries attracted the attention of the fish-culturist, but owing to local circumstances it has, perhaps, been more remarked upon in tropical than in temperate climes. But even in this country we see the anadromous salmon, shad, flounder, and other fishes ascending our rivers for breeding purposes, and in fresh water the eggs of some are hatched, and the young salmon resides in streams until sufficiently old to adopt its parent's mode of life. This brings us to consider whether if marine forms enter fresh water, and their return to the sea is cut off, such an accident is necessarily fatal to their existence. In the brackish water of the Coum river, in Madras, half-beaks (*Hemiramphi*), mullets (*Mugilidæ*), and other marine fishes are captured months after the annual monsoon communication with the sea has been closed. Such changes are gradually effected, and do not appear to lead to any structural modifications in the animals affected. In short, some marine fishes may enter pieces of water which, losing their saline character, become brackish or even fresh, and such changes do not necessarily occasion their death, for they may thrive in such situations.

During the last few years particular attention has been directed to a similar phenomenon in northern Europe, but on a far wider scale. Certain sea fishes, as the four-horned bull-head (*Cottus quadricornis*), a marine sucker (*Liparis barbatus*), and a variety of the common herring, have been found in the northern portion of the Baltic, where that sea is least saline, while they appear to be entirely absent from its southern extremity, where their presence would naturally be expected, had they obtained an entrance from the German Ocean. The existence of these fishes in a comparatively leaner and smaller condition in the Baltic than is seen in their Arctic relatives, has been explained by supposing that they are the remnants of a fauna which formerly extended into the Glacial Ocean. During the later portion of the great ice age most of Finland and the middle of Sweden were submerged, while the Baltic, which was a Gulf of the Glacial Ocean, was closed at its southern extremity. As the Scandinavian continent has become elevated, the Baltic has been cut off from the Arctic Ocean by the northern portions of Norway and Finland, while to the south it has opened a communication with the German Ocean. Consequently its fishes are the descendants of its former glacial marine fauna, and not products of immigration through the Cattegat. These fishes still remain in the northern portion of the Baltic, as if inherited instinct told them that such was the direction in which their ancestors resided. And now the water is almost and at times quite drinkable, and these sea species have come to be residents in almost or quite fresh water.

The foregoing instances show how marine fishes may either voluntarily enter into and reside in fresh waters, as well as how they may be gradually acclimatised to such, provided the change is effected by degrees. Also that not only will some forms thrive, but they may even breed under these new conditions. It has often been observed that strictly marine predaceous fishes will follow anadromous forms from the sea long distances up rivers. I have captured the cock-up (*Lates calcarifer*) as far inland as Pegu, in British Burma; and when investigating the fishes of the Mahanuddi river in Orissa in 1867, I found a species of saw-fish (*Pristis Perrotteti*), up to four feet in length, and at least forty miles from its mouth, in perfectly sweet water, and beyond tidal influence. I likewise obtained others in the river at Pegu. The extension of this species has also been remarked elsewhere, for, in 1857, M. de La Gironnière found it inhabiting the fresh waters of the Laguna de Baij, Luzon, and so did Dr. Meyer in 1872. This last naturalist, having procured a series of examples, compared them with marine specimens from the bay of Manila, when an accurate examination showed no differences ; the changed conditions of life had exercised no appreciable alteration in any of their external characters. In short, these fishes having entered rivers for predatory purposes, may voluntarily remain, or be involuntarily detained there, and consequently take up a permanent abode in this new locality, continuing their species in their new home without necessarily returning to the salt water.

The Earl of Ducie, in 1881, observed upon having spent two months in the Norwegian fjords in his steam yacht. In Midgulen lake, 61° 43′ N. Lat. and 5° 53′ E. Long., he found pollack (*Gadus pollachius*) living in the fresh water. This lake is about five hundred yards from the sea, with which it is connected by a river averaging about twenty yards in width by three feet in depth. In another fjord, which contained fresh water, he took a cod, a coal-fish (*Gadus virens*), and a pollack, all at the inland end of the lake, the last fish being actually in a snow-water stream. The sea fish had complete possession of the lake, which, as in other instances, was entirely fresh.

In 1831 Mr. Arnold, of Guernsey, communicated to the Zoological Society of London some experiments which he had personally carried out in a five-acre lake of varying depth, having a muddy, gravelly, or rocky bottom, and which was principally filled with fresh water. Here for nine months in the year cattle came to drink, but in summer the water was too salt, due to a supply from the sea being received through a tunnel. Bass (*Labrax lupus*), grey mullets (*Mugilidæ*), turbot (*Rhombus maximus*), brill

(*R. lævis*), plaice (*Pleuronectes platessa*), soles (*Solea vulgaris*), and smelt (*Osmerus eperlanus*), were introduced and throve, while the mullet, it was remarked, bred as freely as if they resided in the sea, and Sir J. Gibson-Maitland has hatched numbers of this latter fish in his fisheries. Semper mentions that the grey mullets and the bass have been bred successfully for the market in the fresh-water lake of Acqua, near Padua. In 1881, being at Devonport, I was shown a most beautiful piece of water into which a small stream flowed from the adjacent high-lands, while, at its lower end, a tunnel communicated with the backwater, and through which saline water entered at high tides. A long weir prevented entrance of fish into or exit from this lake, and here were many gray mullet and bass living and thriving.

In 1825 a communication was read before the Wernerian Society from Mr. Meynell, of Yarm in Yorkshire, recording how he had succeeded in retaining smelt or sparling in a fresh-water pond which did not communicate with the sea, and how they not only throve but bred for successive seasons. The sole will live and breed in fresh water; and on some having been retained in fresh, and others, of like weight, in saline water, the first at the end of a year were found to have increased at twice the rapidity of those which were kept in salt water. The flounder (*Pleuronectes flesus*) is so much esteemed by the Frieslanders that they naturalise it in fish-ponds. Mr. Bland, of Derriquim Castle, Kenmare Bay, had a vivarium constructed in an inlet guarded by reefs of rocks in Sneem harbour by means of a strong barrier of stones placed across the entrance, but through which every tide flowed and ebbed, leaving a sufficiency of water inside for the fish. Here mullets, whitings, bream (*Pagellus*) soles and plaice succeeded best; haddock likewise did well; but gurnards became pale in colour. Whitings were so tame as to feed out of the hand, and all the various forms assembled at feeding time on the appearance of the tray; they were particularly partial to potatoes.

FISH PASSES.

Fish passes, commonly termed fish ladders, are constructions erected in rivers for the purpose of enabling fish to surmount or pass natural or artificial obstructions, which are either an hindrance to their attaining to their spawning beds or impede their descent to the sea, and which are destitute of free gaps through which they might pass. For, as was most truly observed by the Royal Commissioners in 1860, "every fact elicited during our inquiry bears witness to the conclusion that an open river is the best for all, and that a recurrence to the ancient and clearly pronounced policy of this country, by the removal of obstructions from the water, is the sure and only road to the restoration of the fisheries." Passes, however efficient they may be, are not complete cures to the injuries inflicted by obstructions; for at these places, except in high floods, the gravid salmon will loiter when ascending the stream towards its spawning beds, and the kelt, while descending, will similarly hesitate some time, prior to trusting to this novel and suspicious mode of descent, consequently protection should be afforded at these localities.

Fish passes, which may be constructed of wood, stone, concrete, or iron, can be subdivided into (1) such as assist the fish by means of ladder-steps, or a series of pools, to ascend over the obstacle; or (2) by means of a succession of locks to pass through the obstruction.

About the year 1830, Mr. Smith, of Deanston, invented a salmon ladder, the principle of which he explained to a Select

Committee of the Houses of Commons in 1836. The dimensions of this ladder were as follows: Height of weir, 10 feet; width of ladder at top, 11 feet; length of ladder, 240 feet; ope of ladder, 11 feet by 1 foot; width at foot, 24 feet; breakwater, high, 1 foot; side walls, high, 1½ foot; incline, 1 in 24 feet.

There are not a few sanctioned passes in this country which the fish still persistently refuse to make use of, due in some instances to the steep gradient on which they have been constructed. Good authorities have considered that as a rule the incline should not be more than 1 in 8 feet for an effective salmon ladder.

The passes which have been proposed for assisting fish to ascend through the body of an obstruction are few in number, and scarcely in favour at present, but possibly they have a better future in store for them.

The first proposition of this description which I can find is as follows: In a report made to the Madras Government (1868) from Surgeon Major F. Day respecting fisheries and the weirs across Indian rivers, and proposing employing their under-sluices and vents as fish passes, plans and descriptions were printed and circulated in January 1871. It was suggested employing the vents of the under-sluices as passes, by turning them into a species of lock. Modifications for the purpose of preventing too great a dash of water into these locks were shown to be necessary, while it was stated, that one having been constructed on the scale of an inch to a foot when in England, and having been properly fixed in a stream, some gold carp were tried, and three passed through. A model of the first invention, constructed with the kind assistance of Mr. Mostyn Owen, was placed in the Buckland Museum in 1869.

The Cail "lock-swimming salmon pass" was first described before the British Association in the autumn of 1872, in which year it was designed, the inventor claiming that by its means fish can be taken up falls in every river, however high. The principle, as shown in Mr. Cail's first drawing, planned to overcome a 12 foot dam is by forming a series of locks having a rise of 18 inches each, which, with two extra for floods and freshlets, equals 15 feet level with the highest flood line. Although these locks may be constructed as small as 5 feet square, Mr. Cail prefers them larger, and 3 feet deep. The bottom lock is the largest, while the pass should be designed as to its size, form, and direction of the chambers to suit the nature and form of the ground, while the entrance should be as near to where the fish congregate as possible.

On a similiar principle an upright stair is designed for places where the river banks are not suitable for continuing locks horizontally, but where the water is closed by steep rocky sides at the fall, and where a space can be got in a corner to build a 12 feet square pass, having the lock made either square or by constructing the divisions diagonally across to make the locks triangular. Should the rise of the lock be 16 or 18 inches, it affords abundance of height to carry the locks over each other to any height; and it can be turned on to the bank by a trough, when required, and taken round beyond the obstruction, whether natural or artificial, to the high water. He observes that in these locks "the only current of any consequence is confined to a short space at each opening (or inlet), and is there moderate, with a head of 18 inches, and only extending for a few inches on each side of the opening, all the other parts of each lock being nearly still or quiescent."

DISEASES OF FISH.

Fish are subject to epidemic, endemic, and fungoid diseases, as well as to many other causes or conditions which have a deleterious effect upon their health. These abnormal destructive influences may be (1) consequent upon a poisoned condition of the water; (2) atmospheric conditions and accidental causes; (3) diseases by which they are affected, including those of the ova stage and infancy; (4) fishermen's and poachers' energies, including the injuries occasioned by vermin.

Beginning with how fish are poisoned by the condition of the water in which they reside, the following primary subdivision of the subject may be adopted. This poisoning may be virulent and *direct*, due to its immediate effects upon fish life, or else it may be mechanical, as in such cases where the presence of mud chokes the gills, and occasions suffocation. Or it may be *indirect* by causing the destruction of the living food which exists in the water, or by occasioning or assisting an unhealthy condition of the fish which reside therein; this latter, however, will more appropriately find a place while discussing diseases and their cause.

Commencing with the fresh waters directly destructive to fish life, due to their noxious condition, we find many gradations of impurities. Thus, in May 1865, large quantities of fish were found dead in the Roden, near Wem, in Shropshire, due to an old *gas tank* having been drained into a sewer which emptied itself into the river. The fish were dead for miles, the bottom of the river being literally strewed with them, not a single one being seen alive. In the Teign great destruction of the finny tribe was perceived, due, it was believed, to the presence of *mine-water;* and the county analyst found that sulphuric acid and sulphate of iron largely abounded in the stream. A minnow (*Leuciscus phoxinus*) and a rudd (*L. erythrophthalmus*) were placed in about a pint of water taken from the river near where the stream joins it coming from the Wheal Exmouth Mine. On immersion, they became very agitated, swimming here and there with great rapidity, and springing out of the water. Then their eyes appeared to become distended, they swam on the surface, and in about ten minutes the poor little minnow sank to the bottom and lay on its side. The rudd was likewise affected, and death terminated their sufferings within the hour. Some others were immersed for the brief space of three minutes in water taken from the Teign, and then removed to some clear good water, but they never rallied, and three hours subsequently were found to be dead. *Chloride of lime* is largely employed by poachers in order to poison fish, and scarcely a month passes but that a notice may be read in the police reports of some one having been punished for this offence. But this proceeding may be legalised, provided it is done in a wholesale manner; thus we are informed that the proprietors of the great paper-mills on the Cray river have obtained a special Act of Parliament, freeing them from any penalties which might be incurred from pouring the self-same substance into the stream. The noxious character of the refuse of paper-mills, dye-works, and bleaching-grounds, are unfortunately but too well known, and mostly permitted to continue poisoning rivers, to the partial, and in some places, total annihilation of the fish, as well as affecting the health of human beings or cattle which may incautiously partake of the apparently limpid stream. But this poisoning, though sufficient to kill some forms, may not do so to all, dependent upon the amount and virulence of what is discharged: young fish are first affected; then members of the salmon or trout family; next carp; and least of all the common gudgeon, which will live in very polluted liquor, so it is generally produced in Court by the counsel for the defence of pollutions, swimming about in some of the suspected water, and shown as a proof to the judge and jury how unfounded a charge has been raised.

Artificial root manure, which is formed of bones dissolved in sulphuric acid, has been observed to injure fisheries. From three to five cwt. an acre are necessary, and should this be employed in a field sloping down to a river, and a severe thunderstorm set in just after it has been spread, the surface rain-water which runs off to the river becomes impregnated with it, and that to the certain injury of the fish, and probably the destruction of much of their food. Sheep-dipping has likewise the same effect the *dip* being poisonous to fish. In East Prussia, in 1879, a brewer having about 300 tons of beer unfit for consumption allowed the mass to run off into a pond, with the result of poisoning the contained fish.

I have in India observed rivers flooded at the first burst of the monsoon, and stagnant waters have been washed into them, destroying every living fish, evidently due to some poisonous substance which they contained. I have also seen the flooded Bowany river charged with mud, and many sorts of fish lying dead on its banks, and floating down the current. Natives will likewise throw a dam across a sluggish stream, then by stirring up the mud the fishes will become choked, which causes them to come to the surface to breathe. In Ireland I have seen much the same effect produced from a somewhat similar cause: the season was hot, the water low, some cattle went into a pool formed by a small stream in order to drink, while moving about they so mudded the water that two trout came to the surface nearly suffocated. The grayling, formerly abundant in the Aire, in Yorkshire, were all destroyed in 1824 by the bursting of a peat bog, which became discharged into the river.

The instances which I have adduced demonstrate how noxious and poisonous ingredients finding their way into ponds and sluggish rivers may be immediately destructive to fish life, although not so rapidly to some forms as to others; while the Teign experiment goes to prove that poisons may be imbibed in sufficient quantities to take away life, although the fish has been but a few minutes in the polluted river water, and subsequently transferred to such as is perfectly pure. Floods and waters having large quantities of mud in solution, would seem, in some cases at least, to occasion death by choking the fishes' delicate gills, and thus preventing respiration from being carried on.

It seems probable that steam-boats on rivers do a considerable amount of injury to fisheries; not solely by discharging their noxious residue into the stream, but by constantly keeping up a wash they disturb the banks and the spawn, injuring or even killing the fry, by leaving them in hundreds to perish on the banks on to which they have been washed. Due partly to the great increase of population, and a disinclination to interfere with the employers of labour, some of our rivers, especially near their mouths, may be likened to enormous drains, with the result as seen in the Thames of destroying entire species of fish, as the salmon, which cannot now be said to exist there in a state of nature. For to such an extent are noxious substances discharged into our watercourses, that even in some which are moderately rapid, the poison possesses sufficient virulence to cause immediate death to any fish which come within the influence of its agency. Occasional floods clear out the waterway in some rivers, while the mouths of drainage pipes are commonly near the banks, and thus the salmon has a chance of ascending, provided it keeps to the centre of the stream. But the fry mostly keep more to the shallows, and along the margins, and consequently when they are descending to tidal waters they have to pass through the most impure portions of the stream, which, if it does not destroy many, must render them in such a sickly condition as to fall an easy prey to the predacious forms of fishes and fish-eating animals, which lurk about the estuaries of rivers. The results of Hoffmeister's experiments in Germany upon the effects of sewer-matter upon fish tend to show the noxious character of chlorine, and of manufacturing refuse in which sulphur exists. When water was mixed with these substances, the fish placed in it turned on their sides and displayed signs of approaching death, but some recover if removed to fresh water, others do not. Resistance to impurities increases with the size of the fish, and their sensibility to free acid and alkalies is small, but quicksilver and salt of copper are rapidly injurious to them. Salts of iron and alumina act in various ways, according to the character of the fishes operated upon, carp possessing ten times the resisting power of trout. Small quantities of chloride of calcium were found to have no injurious effect upon trout, even after several hours' trial. The higher the temperature the greater the noxious effects of substances of a poisonous nature; consequently fishes can exist during winter months in impure water longer than they are able to do in summer.

Sawdust in rivers, from the time of Pontoppidan until the present, has been deemed deleterious to salmon fisheries. It is said to subside in rivers, filling the place where fish eggs ought to develop with impure and injurious matter, occasioning a fatal fungus.

Passing on from fresh to saline waters we find that both the direct and indirect causes of destruction present in ponds, canals, and rivers, may likewise be in operation in the sea, the water of which may be so noxious as to at once destroy the residents, certain forms succumbing more rapidly than others. Also the food upon which the fish subsist may be diminished, due to some extraneous cause, rendering the locality totally or partially unable to support the shoals which generally arrive at certain seasons, in order to obtain food or seek a locality which they may deem desirable for the continuation of their species. Poisonings of the sea-water for hundreds of miles in extent are known to occur off the coast of India, but such phenomenon have not been observed in our seas of late years; but in a Parliamentary report into the state of the Salmon Fisheries, in 1825, it is stated that 30 years previously, so great was the mortality among certain fish, that ships sailed through many leagues of the North Sea where the surface was covered with dead haddock.

I will now pass on to the second subject of causes of destruction, or such as are due to atmospheric conditions and accidental influences. A low temperature has frequently been observed to be disastrous to some of the finny tribes, sand smelts (*Atherina*), surprised by a sudden frost in the shallow waters of a harbour, have been killed in numbers. Congers are very sensitive to cold, at which times they become what is commonly known as "blown," and float on the surface nearly or quite dead. Near Cork, in 1841, many died due to frost, and others were easily captured, although the water was from 40 to 60 feet deep, and brackish; while there are many recorded instances of eels and other fish succumbing due to excessive cold. On the other hand, some forms will recover after they have been apparently frozen ; thus, Mr. Wright observed, in 1866, that during a very severe frost, a few winters ago, some gudgeons, which had been kept in a fish-can filled with water, became completely frozen into literally a mass of ice ; believing them to be dead, they were flung on to a manure heap, and slightly covered by straw. A few hours subsequently they were found to be alive and brisk. Thirty-five gold-fish were in a pond at Dumfries, which was 3 feet deep ; this was frozen into one solid mass, subsequently the fish were thawed out, and twenty-five entirely recovered. Livingston Stone remarked having repeatedly witnessed the resuscitation of frozen trout, pickerel, and perch, on thawing them out in fresh running water, even after they had been carried for miles, but that it is only under certain circumstances that they will revive. If caught on a cloudy day, when it is freezing hard, provided they are not hurt by the hook, and they freeze immediately upon being thrown on the ice, they will revive on being thawed out. But if allowed to toss about in the sun, on a clear day, and probably not frozen for an hour or two after they are caught, they will not recover. Sir John Franklin, in his first overland journey to the Polar Seas, states that the fish froze as they were taken out of the nets, and in a short time became a solid mass of ice, and by a blow or two of the hatchet were easily split open, when the intestines were removed in one lump. If in this frozen state they were thawed before the fire they recover their animation. A carp was observed to recover after it had been apparently frozen thirty six hours. Experiments have shown that no animal completely frozen is susceptible of revivification, as freezing disorganises the blood; but animals may be surrounded by ice without being frozen themselves, unless the temperature is very low. During the winter of 1880–81 a great destruction of salmon ova occurred in Highland rivers and streams, through the displacement of spawning beds by masses of ice, which the severe frosts accumulated, and numbers of salmon were found dead imbedded in it.

Electrical disturbances may be the accidental cause of the death of fish in tropical countries; hail and thunderstorms united will sometimes depopulate rivers. In 1879 the occupants of a small fish-pond in the Duchy of Nassau were destroyed by a flash of lightning, on the following morning all being observed dead on the surface, and presenting the appearance of having been half boiled. On July 7th, 1865, a flash of lightning struck a house in Hamburg, from which at about 200 feet distance, in a shady spot in the garden, and in the open air, was a large fresh-water aquarium, containing forty-three fish, consisting of tench, carp, dace, roach, gold-fish, eels, and two species of loach, &c. At the moment the flash of lightning occurred, every one of these fish became suspended perpendicularly downwards in the water, with their tails at the surface, feebly and vainly attempting to swim towards the bottom of the tank, with all their fins strangely attenuated, as transparent as fine tissue-paper, and densely covered on both sides with myriads of fine air-bubbles, while their heads and bodies were not so covered. In less than half an hour forty-one were dead, strongly curved, almost in the form of semi-circles and already fast decomposing; two gradually recovered upon being placed in running water. Direct heat on water may be very destructive to fish-life, not only among the young but also to adults. During the dry weather in the Orkneys, in 1882, the water in Loch

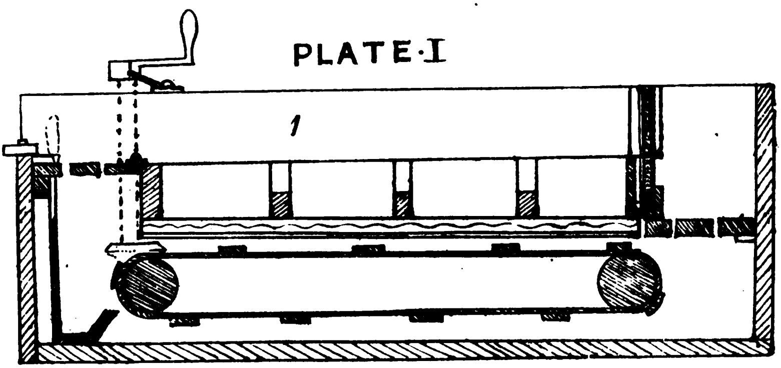
Harray, on the West Mainland, was reduced in volume, and rendered tepid by a succession of hot days. The trout assembled in shoals at the mouths of the burns, and were slaughtered in thousands by netting. Of course the coolest places were at spots where streams emptied themselves into the Loch. While there are few who have observed young fish being reared in ponds, but have not been made unpleasantly aware of the fact, that if the temperature rises above a certain point the fish die.

Gales are also occasionally destructive to fish, as on April 13th, 1874, when a violent one broke over Scilly, and large fish as conger, hake, ling, &c., were tossed about in their watery homes, and at last flung by hundreds on the rocks. Some were denuded of scales, others had their heads stove in, while even those which live at rocky bottoms fared no better than their neighbours. A high tide may prove mechanically destructive in a river; thus in October 1881, between Kew and Mortlake, a great quantity of small roach were left on shore by a receding tide; as many as three and four thousand were returned alive to the river. In Norfolk, it has been remarked, that should the salt water overflow localities generally filled by fresh water, the first fish to suffer are the pike, bream, and roach. Tench are nearly exempted, due to their remaining in the broads, to which sea water seldom extends, but, should it do so, they perish before the bream. Perch will bear a strong admixture, and eels seem to resist saline influence altogether.

PLATE I.

1. A. S. Collins' Fish Spawning Screen.
2. " " " , full view.
3. " " " , top.
4. Brackett's Hatching-box.
5. Lund's Hatching-box.
6. Slack's Hatching-Grill box.
7. Ricardo's Hatching-box for adhesive eggs.

PLATE I



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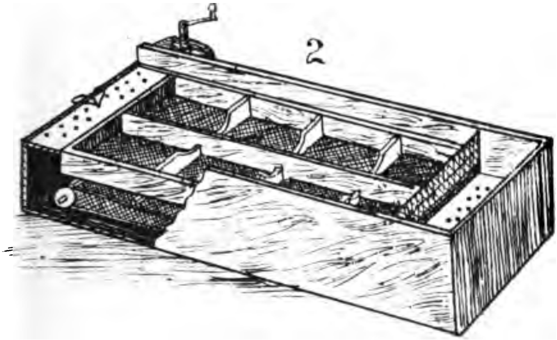

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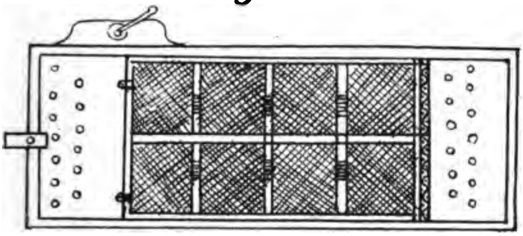

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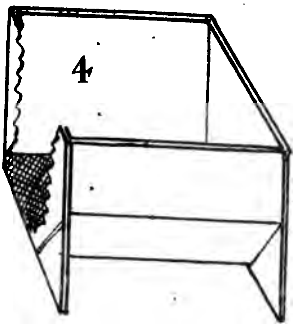

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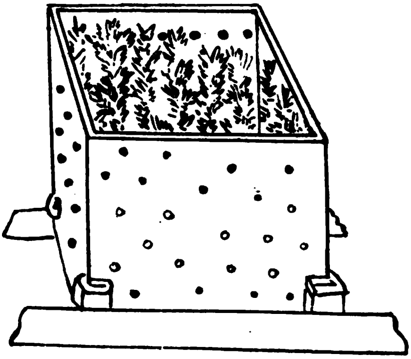

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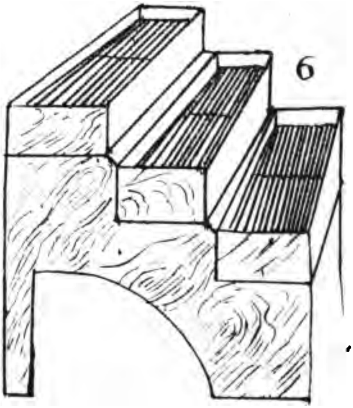

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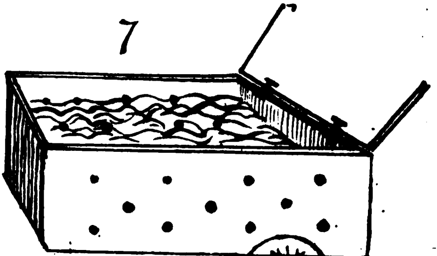

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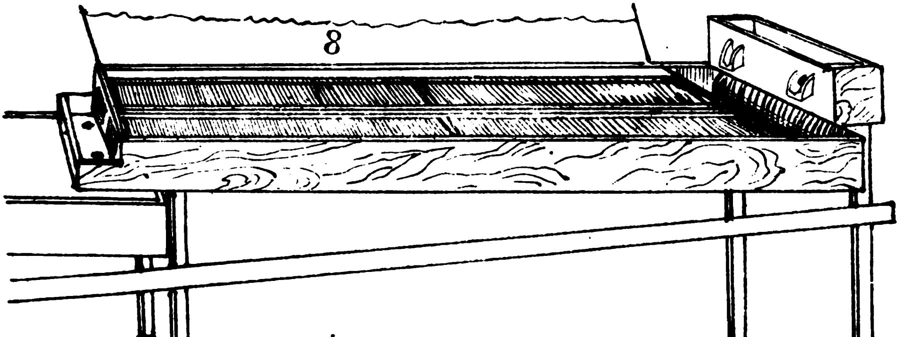
PLATE II.

8. Sir Jas. Maitland, Bart., Howietoun Fisheries Hatching Grill.
9. Section of Grill, showing method of fixing glass tubes.
10. Hatching-box with air-tight tin tubes for support.
11. Bryan's Fish Hatching-box.
12. „ „ „ , top, showing outriggers, or supports.
13. Wave Hatching-box.
14. Chase's Hatching-jar.

PLATE II



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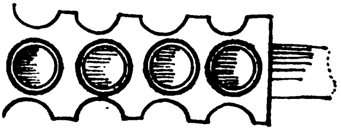

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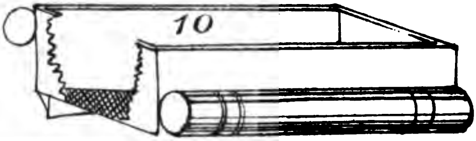

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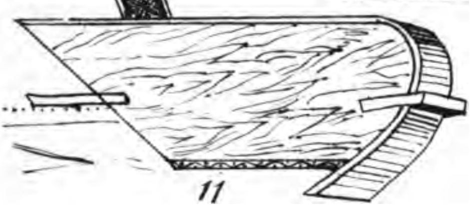

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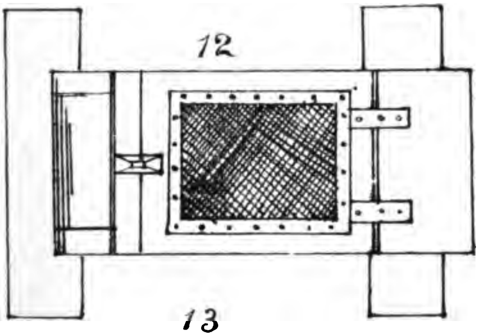

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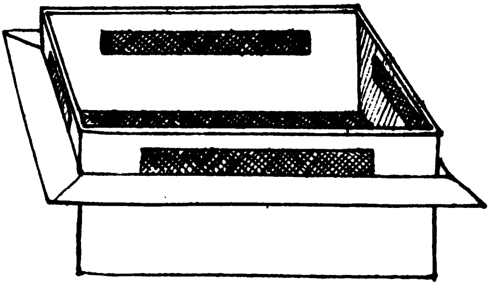

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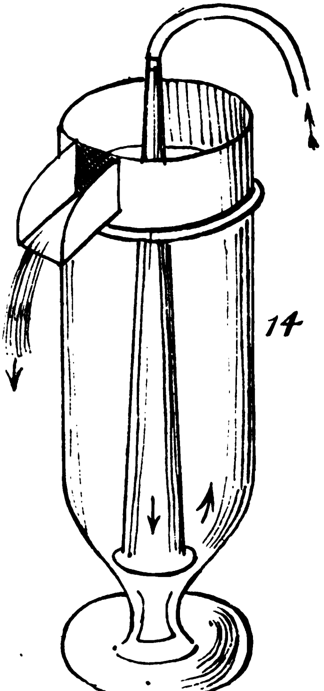

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PLATE III.

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15. Ferguson's Plunging Buckets.

16. „ „ „ , section.

17. „ „ „ , machinery causing the slow rise and rapid fall of the buckets.

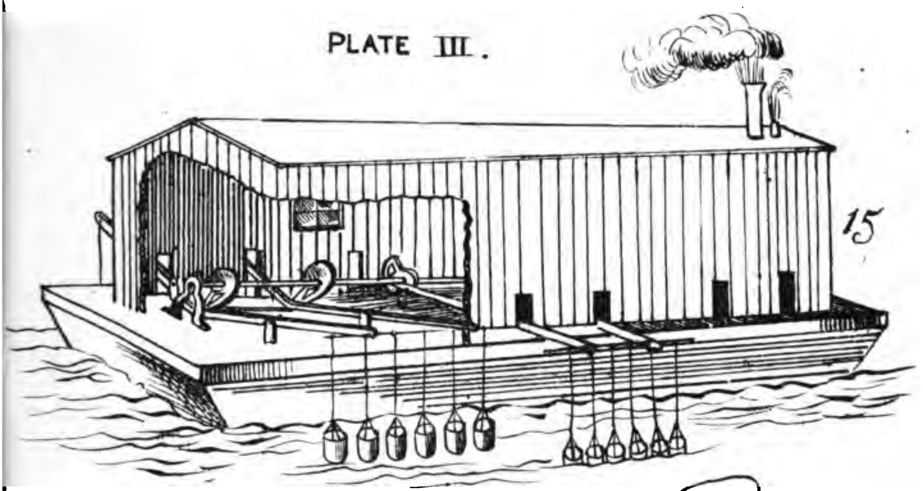
18. Wilmot's Hatching-jar.

19. Wright's submerged Hatching-box.

20. Ferguson's Hatching-jar.

20*a*. Fish Collecting Tank.

PLATE III.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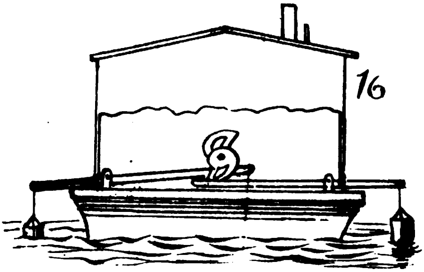
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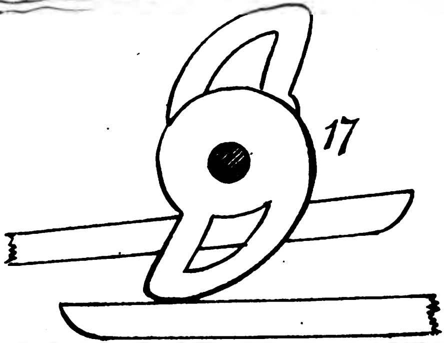
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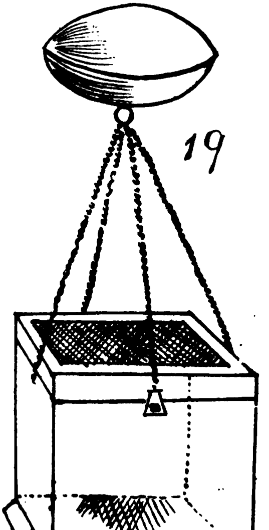
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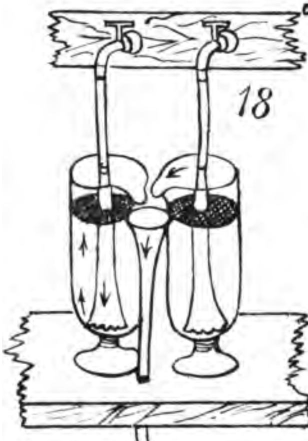
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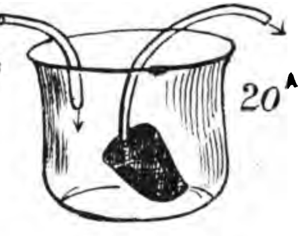
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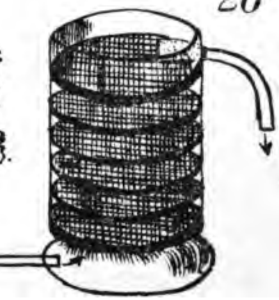
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